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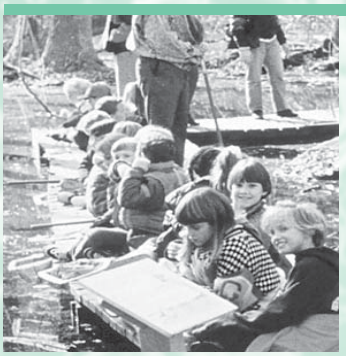


The Science Content Standards for Kindergarten Through Grade Five

The Science Content Standards for Kindergarten Through Grade Five

This chapter incorporates the *Science Content Standards,* providing an explanation of the science underlying the standards and outlining activities that are consistent with the objectives of the standards. The activities included in this chapter are examples of the ways in which the standards may be approached. They are not to be interpreted as requirements for the science classroom or for inclusion in instructional materials, thus explaining the frequent use of helping verbs, such as *can, may,* and *should.*

The science standards are set forth in terms of what students know. Therefore, mastery of an individual standard is achieved when students have actually learned the fact, skill, concept, principle, or theory specified. Mastery does not occur simply because students have received a particular explanation or participated in a particular activity.

The elementary school science program provides the foundational skills and knowledge students will need in middle school and high school. Students are introduced to facts, concepts, principles, and theories organized under the headings of physical, life, and earth sciences. They learn essential investigation and experimentation skills that will continue to be developed through high school. Elementary school students respond positively to well-structured activities and expository reading materials that connect the world around them to the science content. Students raise questions, follow their curiosity, and learn to be analytical. They are encouraged to practice open and honest expression of ideas and observations; they learn to listen to and consider the ideas and observations of other students. Both teachers and students need to enjoy the adventure of science.

This enjoyable adventure includes the school library-media center as a natural partner in science teaching and learning. The books and other resources available in the school library enhance and expand an interest in and understanding of science. When the school library-media center is appropriately staffed with a credentialed library-media teacher, information literacy instruction can be integrated into regular science instruction.

Safety is always the foremost consideration in teacher modeling and the design of demonstrations, investigation and experimentation, and science projects, both at the school site and away from school. Teachers must become familiar with the *Science Safety Handbook for California Public Schools.*[1] It contains specific and useful information relevant to classroom teachers of science. School administrators, teachers,

parents/guardians, and students have a legal moral obligation to promote safety in science education. Safety must be taught. Scientists and engineers in universities and industries are required to follow strict environmental health and safety regulations. Knowing and following safe practices in science are a part of understanding the nature of science and scientific enterprise.

Kindergarten Science Content Standards

Science study provides children in kindergarten with a unique opportunity to explore the world around them. It is important to teach kindergarten students to be objective observers and to know the difference between an observation and an opinion. Students begin their study of science by observing and noting the similarities, differences, and component parts of materials, plants and animals, and the earth. They also observe processes and changes over time. Observational activities must always be designed with safety as a foremost consideration.

Students learn how to classify, compare, sort, and identify common objects. They expand their skills in descriptive language by learning to observe, measure, and predict the properties of materials. Activities related to freezing, melting, and evaporation can provide ways to stimulate classroom discussions. Studies of plants and animals, landforms, and weather allow students to recount personal stories and speak of familiar experiences and interests. In doing so they learn new vocabulary and have opportunities to practice mathematics. In the kindergarten curriculum, as students listen to stories, teachers may use important strategies for teaching comprehension by (1) using pictures and context to make predictions; (2) retelling familiar stories; and (3) answering and asking questions about essential elements.

STANDARD SET 1. Physical Science

Standard Set 1 begins the study of the properties of matter and its transformations. While learning these standards, students build a foundation for making observations and measurements. The three standards call attention to the properties of common objects (most of which are solids) and to the properties of water. Teachers introduce the term *physical property* to students by asking them to observe the properties of a variety of objects. Students will be able to predict on the basis of some initial observations what will happen under different conditions rather than make random guesses.

1. Properties of materials can be observed, measured, and predicted. As a basis for understanding this concept:

a. *Students know* objects can be described in terms of the materials they are made of (e.g., clay, cloth, paper) and their physical properties (e.g., color, size, shape, weight, texture, flexibility, attraction to magnets, floating, sinking).

Students learn how to compare objects on the basis of characteristics and physical properties, such as color, size, shape, weight, texture, flexibility, attraction to magnets, and floating and sinking in water. By working with objects and noting

their physical properties and characteristics, students develop their ability to make observations and use appropriate academic science language that is expressive and descriptive.

Teachers may provide a variety of objects that students can investigate by using the senses of sight, sound, and touch. Activities involving the sense of smell and taste should be done only at home under parental supervision. In the classroom students use sight, sound, and touch to sort objects according to their physical properties.

The next step is for students to sort objects according to properties that do not manifest themselves directly to those three senses. For example, they might test different objects for the ability to float or sink in a small container of water. The list might include wood blocks, sponges, solid rubber balls, metal washers, small rocks, and Styrofoam balls. Students can test a few of these objects by observing which ones sink or float, then test their predictions experimentally. They may be surprised to see that a heavy piece of wood will float, but a lighter metal washer will sink.

Those observations are important to discuss because the behavior of the object depends on its density and not its weight. Density is a topic that is covered formally in grade seven, but students need to get a "feel" for it in earlier grades. Similarly, the property of magnetism is discussed in some detail in grade four, but students in kindergarten may enjoy learning that magnets stick only to certain types of metal and that the most common magnetic metal is iron.

1. b. *Students know* water can be a liquid or a solid and can be made to change back and forth from one form to the other.

Observing the change from ice to liquid water and back to ice builds students' understanding that a substance may have both solid and liquid forms. Freezing and then melting water shows students that the water is returned exactly to its original state. A teacher may consider reading a story about winter ice and snow to the class to help develop vocabulary and comprehension.

1. c. *Students know* water left in an open container evaporates (goes into the air) but water in a closed container does not.

Students can observe a cup of water covered or uncovered in the classroom during several days or weeks. The gradual evaporation of water offers an opportunity for students to record observations and develop vocabulary related to time periods that extend beyond a single day. The rate of evaporation will depend on the temperature and room humidity and on the type of container chosen. Stories in which it rains and then the water dries up may also provoke interesting discussions. When rain forms puddles on the ground, some of the water may evaporate and some of it may sink into the soil where it can be taken up by plants.

Students may observe evaporation in classroom demonstrations. Water vapor in the air may be condensed to liquid water and collected on a cold surface. For

example, a teacher might hold a hand-mirror over a container of hot tap water to show that the water vapor rises and fogs the mirror and that small droplets of water may form.

STANDARD SET 2. Life Sciences

Kindergarten students expand their observational skills and vocabulary by learning to describe the appearance and behavior of different animals and plants. They have the opportunity to discuss the principles of structure and function at a simple level. For example, most birds and many insects have wings and can fly, but birds have feathers and insects do not. There are many outstanding fictional stories that the teacher may select to read to the students, perhaps from the school library-media center. Students learn that stories may give plants and animals attributes that are funny but not real. Although authors may use anthropomorphism to engage the interest of young people and exercise their imagination, such a literary technique should not be confused with scientific procedures and fact. Teachers may use many expository texts to enrich the observation of plants and animals in a classroom.

2. Different types of plants and animals inhabit the earth. As a basis for understanding this concept:

a. *Students know* how to observe and describe similarities and differences in the appearance and behavior of plants and animals (e.g., seed-bearing plants, birds, fish, insects).

Teachers guide students to learn that all plants and animals need air, food, and water to grow and be healthy. Students also learn that most animals are able to move about from place to place, which helps them find food to eat. Terrestrial plants, on the other hand, are usually rooted in one place and must obtain their nutrients and energy from the surrounding air, soil, water, and sunlight.

2. b. *Students know* stories sometimes give plants and animals attributes they do not really have.

Real plants and animals do not talk, wear clothing, or walk like humans. Scientific observation of plants and animals helps students in kindergarten to understand the difference between characteristics of the real world and of fantasy.

2. c. *Students know* how to identify major structures of common plants and animals (e.g., stems, leaves, roots, arms, wings, legs).

Students increase the detail of their understanding of plants and animals as they learn about the major structural components of common plants and animals and their functions. For example, students might plant some seeds in pots, care for the plants that sprout, and note how the different structures (such as stems, leaves, and

roots) change during growth and development. A comparison of different leaves is also instructive. Leaves that are good to study have smooth or jagged edges; are wide or narrow; and are of a different color, odor, or texture. Keeping some small animals (such as goldfish and hamsters) in the classroom will provide opportunities for students to learn new vocabulary related to major structures. Students should also learn that scientists are responsible for the ethical care of laboratory animals and that classroom animals deserve no less care (*Education Code* Section 51540).

STANDARD SET 3. Earth Sciences

Mountains, valleys, plains, rivers, lakes, and oceans are all features of the surface of Earth. Forces within Earth uplift the land; and the actions of wind, water, and ice carve Earth's surface into topographic features. Contrasts between rivers and oceans, mountains and deserts, and hills and valleys can become the natural settings for students to begin studying the earth sciences. Changing weather conditions (such as rain, wind, and temperature) provide students with opportunities to make observations and measurements. Recording changes in the weather provides a rich opportunity for class discussion and builds listening comprehension.

The materials that make up Earth's surface provide resources for human activities. Students learn that human consumption leads to waste that must be disposed of. This understanding will help them appreciate the importance of recycling and conserving Earth's resources.

3. Earth is composed of land, air, and water. As a basis for understanding this concept:

a. *Students know* characteristics of mountains, rivers, oceans, valleys, deserts, and local landforms.

Students can explore the variability of landforms by means of tangible experiences (such as making direct observations, hearing stories and seeing pictures, and making models on sand/water tables). They learn to identify the mountains, rivers, oceans, valleys, deserts, and other landforms in photographs or models. This activity will also help improve their vocabulary for describing things.

3. b. *Students know* changes in weather occur from day to day and across seasons, affecting Earth and its inhabitants.

Students know that they do not wear the same clothes on a wet, windy day as they do on a hot, sunny day. They now need to extend their concept of the consequences of weather changes beyond their personal lives. Students make weather observations and note how the weather changes over a period of days, weeks, and months. They observe the generic effects of weather and seasons on the land and living organisms.

3. c. *Students know* how to identify resources from Earth that are used in everyday life and understand that many resources can be conserved.

Students need to learn the connection between materials and the resources from which the materials were derived. Students learn the importance of science in understanding the need for good air to breathe and clean water to drink. Students may explore ways in which to conserve, recycle, and reuse materials, especially within the classroom and school site environment. It is important they learn that everything has an origin. For example, drinking water is derived from streams and lakes, wood and paper from trees, and bricks and metals from Earth.

STANDARD SET 4. Investigation and Experimentation

The ability to observe and describe common objects develops early and is enhanced by kindergarten instruction when students are introduced to the properties of solids and liquids, plants and animals, and landforms and weather conditions. Students can also be taught to compare and sort objects on the basis of the objects' properties and be encouraged to use mathematics to communicate some of their observations.

4. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

a. Observe common objects by using the five senses. [*Caution:* Observational activities associated with tasting and smelling should be conducted only under parental supervision at home.]

b. Describe the properties of common objects.

c. Describe the relative position of objects using one reference (e.g., above or below).

d. Compare and sort common objects by one physical attribute (e.g., color, shape, texture, size, weight).

e. Communicate observations orally and through drawings.

Grade One Science Content Standards

Students in grade one learn about the general properties of solids, liquids, and gases. They also learn about the needs of plants and animals and the functions of some of their external structures. Students also learn how to use simple weather-recording instruments, such as thermometers and wind vanes, and discuss daily and seasonal changes in weather. Students in grade one are adept at identifying the characteristics of objects and can either record those observations through pictures and numbers or begin to use written language. They can learn to make new observations when discrepancies exist between two descriptions of the same object or phenomenon.

The English–language arts standards require students to write brief expository descriptions about people, places, things, and events by using sensory details. Those expository descriptions may be aligned with the science standards that require students to record observations and data by using some written language. Teachers should guide students to respond to *who, what, when, where,* and *how* questions. Students expand their vocabulary by learning appropriate grade-level scientific terms (such as *freezing, melting, heating, dissolving,* and *evaporating*).

STANDARD SET 1. Physical Sciences

Students learn the general differences and similarities between properties common to all solids, liquids, and gases. The physical sciences standards in grade one provide a foundation for the study (in grade three) of evaporation and the changes in states of matter that may occur when solids and liquids are heated.

1. Materials come in different forms (states), including solids, liquids, and gases. As a basis for understanding this concept:

a. *Students know* solids, liquids, and gases have different properties.

Solids have definite shapes, meaning they are rigid and occupy a specific volume. This attribute distinguishes solids from liquids and gases whose fluid nature (or ability to flow) results in their shape being determined by the shape of whatever vessel contains them.

Teachers may demonstrate the properties of a solid by collecting a variety of solid objects of different shapes, sizes, weights, and textures. They demonstrate the fluid nature of a liquid by pouring water between same-sized measuring cups of different shapes. This demonstration shows that each cup holds the same amount of liquid even though the shapes are different. Distorting a partially inflated balloon into a variety of shapes shows that gases do not have a definite shape, and

pushing the balloon into a container of water shows the amount or volume of water excluded by the gas.

Students can draw pictures and tell or write stories that illustrate the differences between the properties of solids, liquids, and gases.

1. b. *Students know* the properties of substances can change when the substances are mixed, cooled, or heated.

Students can be taught that melting requires heating and freezing requires chilling. It may be helpful to use a thermometer to establish whether the temperature of a substance is increasing or decreasing before and after melting occurs. As ice water is heated, the temperature does not increase until the ice is melted. Students should begin to understand that some changes are reversible (e.g., ice melting) and some are irreversible (e.g., an egg cooking). Salt dissolved in water and recovered through evaporation may be cited as another example of a reversible process. Mixing baking soda with vinegar produces irreversible change, marked by the carbon dioxide gas bubbling up from the vinegar as the baking soda converts into soluble sodium acetate and water.

STANDARD SET 2. Life Sciences

Students in grade one are ready to focus on the favorable habitats (usually including air and soil), water, and energy supply (sunlight or food) that living organisms need to survive. Students will learn how plants and animals live in different environments and will discuss the relationship between structural form and function.

2. Plants and animals meet their needs in different ways. As a basis for understanding this concept:

a. *Students know* different plants and animals inhabit different kinds of environments and have external features that help them thrive in different kinds of places.

Students learn about the types of organisms that live in different environments and the ways in which they have adapted to their surroundings. Marine mammals off the Pacific coast typically have thick, blubbery skin (e.g., whales) or thick fur (e.g., sea otters) to withstand the cold water. Giraffes have long necks that help them to reach leaves near the tops of trees and spot predators from great distances. Those examples of adaptations are ones that students can readily discuss. Many stories and videos about plants and animals can help students learn about life on Earth.

2. b. *Students know* both plants and animals need water, animals need food, and plants need light.

Learning what plants and animals need to survive is one of the foundations of ecology. Both plants and animals need water and air. Both also need a source of energy. Plants absorb sunlight, and animals eat food to meet their energy requirements. Plants and animals obtain what they need to survive through the environmental adaptations described above.

If plants are kept in the classroom, students can learn about their needs by caring for them. Students may enjoy field trips or walks in locations where shrubs and grasses attract small animals (particularly birds, lizards, and insects). To supplement those activities, the school library has many books with good stories about plants and animals that live in a variety of environments.

2. c. *Students know* animals eat plants or other animals for food and may also use plants or even other animals for shelter and nesting.

This standard introduces students to the fact that all living organisms in an environment are interdependent. For example, some birds nest in shrubs and trees; insects (such as fleas) may inhabit dogs, cats, and other mammals. Animals may assist plant reproduction by spreading seeds.

Students can observe that insects eat the leaves of shrubs and grass and that this activity will attract additional small animals, such as birds and lizards, which eat the insects. Discussions of such observations introduce students to the idea of a food chain. Teachers should point out to their students that people are at the top of the food chain.

2. d. *Students know* how to infer what animals eat from the shape of their teeth (e.g., sharp teeth: eats meat; flat teeth: eats plants).

This standard introduces the biological concepts of structural form and function, which are discussed extensively in later grades. A cat's sharp, pointed teeth are well suited for ripping and tearing the meat it eats, and the flat teeth of a cow are well suited to chewing and grinding the tough grasses it consumes. Students can study different specimens of teeth, including skeletal examples and fabricated models. They can find pictures of different kinds of teeth (carnivores and herbivores) in library books. Students can examine their own teeth by using mirrors and observe, record, and report to the class which teeth they use (front teeth or back teeth) when eating different types of food. The relationship between teeth and the food that animals eat may be taught during a field trip to the zoo or when a naturalist speaks to the students.

2. e. *Students know* roots are associated with the intake of water and soil nutrients and green leaves are associated with making food from sunlight.

This standard is complementary to Standard 2.d as it emphasizes the relationship between plant structures and their functions. Students learn that roots take in water and nutrients from the soil. Green leaves are the sites where photosynthesis turns sunlight into food. If students have plants growing in the classroom, they may observe and record how the plants respond to different growing conditions. For example, a plant growing near a window may turn its leaves toward the light source and change its direction of growth to improve its ability to make food.

STANDARD SET 3. Earth Sciences

Students learn that each season has its own predictable range and trends of weather conditions. They also learn how to use simple equipment to measure weather conditions. To be prepared for studies in subsequent grade levels, students should learn that Earth receives energy from sunlight and that the warming of Earth has a strong influence on the weather.

3. Weather can be observed, measured, and described. As a basis for understanding this concept:

a. *Students know* how to use simple tools (e.g., thermometer, wind vane) to measure weather conditions and record changes from day to day and across the seasons.

Students learn how to use a thermometer and a wind vane to measure weather conditions. They may also make a simple rain gauge to improve the quality and detail of their weather observations, measurements, and records. In discussing their findings, they have opportunities to improve their vocabulary and expressive language. Students should have experience in recording day-to-day and seasonal changes in weather, but teachers should limit the time spent on those activities. For example, if students were to spend only ten minutes per day making measurements and discussing trends in the weather, the instructional time dedicated to this activity would amount to 30 hours over the course of a school year.

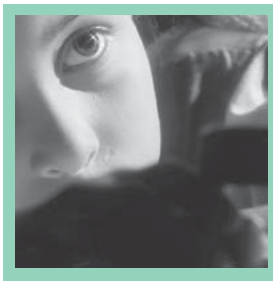
3. b. *Students know* that the weather changes from day to day but that trends in temperature or rain (or snow) tend to be predictable during a season.

Teachers may wish to keep an eye on the weather report and allot instructional time to record weather conditions during a week in which precipitation or high winds are expected. They may also have students record data during a different week in which the weather is expected to be relatively stable. In bringing students'

attention to those two differing sets of data, teachers may lead a spirited discussion. Although it is difficult to predict the weather, teachers should not encourage uninformed guesses. Historical data on temperature, wind, and rainfall conditions are typically collected for every city, often by stations located at airports. Those data are freely available on the Internet and are a useful resource.

3. c. *Students know* the sun warms the land, air, and water.

Radiation from the Sun is ultimately responsible for atmospheric circulation and the weather, a fact that is introduced in grade one and mastered in grade five. Students in grade one may be made aware of the warming effect of the Sun's rays on their skin and may be shown that the air, land, and water are similarly warmed. For example, students can see that on a sunny day the asphalt of their playground is cool in the morning but hot by midday. On a cloudy day the asphalt may stay cool all day.



STANDARD SET 4. Investigation and Experimentation

Students continue to develop the ability to make quantitative observations and comparisons by recording and using numbers. Recording requires careful observing, comparing, and establishing the order of objects and events. Not to be overlooked is teaching students to revisit their observations. A revisit is best done when students find that they have different descriptions of the same object or event. Also important is the fact that an observation of change depends on having a "fixed" reference point. An object is known to have moved only because its position has changed in relation to a reference point.

4. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- **a.** Draw pictures that portray some features of the thing being described.
- **b.** Record observations and data with pictures, numbers, or written statements.
- **c.** Record observations on a bar graph.
- **d.** Describe the relative position of objects by using two references (e.g., above and next to, below and left of).
- **e.** Make new observations when discrepancies exist between two descriptions of the same object or phenomenon.

Grade Two Science Content Standards

In the physical sciences students in grade two learn about forces (pushes and pulls) and some common phenomena (such as gravity, magnetism, and sound). In the life sciences they learn about the life cycles of animals and plants and the basics of inheritance. Dogs always reproduce puppies, never kittens or hamsters; however, not all puppies look alike. There is both similarity within a species and natural variation, some of which is caused by the environment. In the earth sciences students learn that rocks are composed of different combinations of minerals, that smaller rocks and soil are made from the breakage and weathering of larger rocks, and that soils also contain organic materials. Students are introduced to fossils and the evidence they provide about Earth's history.

The content standards for both science and mathematics specify writing; measuring; simple graphing; and making drawings to record, organize, interpret, and display data. Students practice measuring (with appropriate tools) length, weight, temperature, and liquid volume, expressing those measurements in standard metric system units. Students in grade two should learn to organize their observations into a chronological sequence and be able to follow oral instructions for an investigation.

STANDARD SET 1. Physical Sciences

The primary aim of the physical sciences standards for students in grade two is to develop a foundation for the study of motion and force that will be developed still further at later grade levels. At a very basic level, students should learn about the forces of gravity and magnetism and the ability of vibrating objects to make sounds.

1. The motion of objects can be observed and measured. As a basis for understanding this concept:

a. *Students know* the position of an object can be described by locating it in relation to another object or to the background.

Students learn how to locate an object by measuring its distance and noting its direction in relation to another object that serves as a reference point. It does not matter what the reference object is as long as it is stationary. Distances are measured by using metric system units (such as meters [m] and centimeters [cm]). Students also learn to describe the position of an object by its location in relation to a pattern in its background or to a very distant object.

1. b. *Students know* an object's motion can be described by recording the change in position of the object over time.

This standard helps to develop concepts of motion (such as speed, velocity, and acceleration) that are formally taught in higher grades. Students in grade two may simply observe and record the position of objects at intervals of time and note the changes in speed and direction along the path the object travels. Some objects will travel farther than others in a fixed time and therefore travel faster.

1. c. *Students know* the way to change how something is moving is by giving it a push or a pull. The size of the change is related to the strength, or the amount of force, of the push or pull.

Once set in motion, an object will move in a constant direction and at a constant speed unless it is pushed or pulled. A ball at rest will remain at rest unless it is given a push or a pull. Speeding up, slowing down, and changing direction all require a push or pull. The friction between surfaces that slows objects down may be considered a pull. Pushes and pulls may be related to corresponding changes in the position of an object and the speed or the direction in which it is traveling.

The term *force* is introduced into the vocabulary and will be used more formally in later grade levels. Students in grade two learn to think about pushes and pulls as forces and the strength of the push or pull as the strength or magnitude of the force. When students kick or throw a ball, the effort they put into the action of kicking or throwing is related to the force (push) that is applied to the object and therefore the speed and distance it will travel. They will also understand that the bigger the change in the object's motion, the bigger the push or pull that is required.

1. d. *Students know* tools and machines are used to apply pushes and pulls (forces) to make things move.

Students become acquainted with some of the methods by which tools and machines transmit or apply pushes and pulls in order to make things move. The blow (push) of a hammer will move a nail into a piece of wood. A hit (push) by a baseball bat will change the direction of motion of a pitched ball. A car's engine applies a force to turn its wheels, causing the car to move. Students are taught that machines and tools allow people to apply and control forces, some of which may be much greater than they themselves could create. In grade three students will learn that a source of energy is needed for machines to do work and create the forces that move heavy objects or move objects at great speeds.

1. e. *Students know* objects fall to the ground unless something holds them up.

Gravity is a fundamental attracting or pulling force. A table, chair, shelf, or bench can support an object by opposing this pull. From a student's perspective an object seems to push down on whatever supports it. By grade eight students will

learn the supporting object is also pushing back. Students in grade two should be taught that all objects in the universe are pulled toward all other objects by a force called *gravity.* Bigger, more massive objects pull more strongly than lighter ones. When a child drops a toy, the toy falls toward the ground instead of floating up because the force of Earth's gravity pulls on the toy. (Of course, the gravity of the toy pulls on Earth equally as well.) Earth's gravitational force on an object is called the object's weight.

1. f. *Students know* magnets can be used to make some objects move without being touched.

The poles of magnets either repel (push) or attract (pull) one another. The fact that magnetic pushes and pulls happen at a distance without direct contact should be carefully noted. Students may, for example, observe magnetic attraction and repulsion being transmitted through materials such as paper or tabletops. This concept will give students an understanding of force at a distance and of the ability to apply pushes and pulls to objects without touching them.

Many activities may be done with magnets. Teachers are encouraged to have bar and ring magnets with distinct north and south poles rather than refrigerator magnets made of alternating poles. In this way students can discover the north-south attraction and the north-north or south-south repulsion. Students may sprinkle iron filings on a piece of paper and observe what happens to the pattern that the filings make when a magnet moves under the paper. This experiment provides further evidence that magnets do not have to touch materials to attract or repel them.

1. g. *Students know* sound is made by vibrating objects and can be described by its pitch and volume.

The primary objective is for students to know that vibrations (back and forth motions) produce sound. They should be able to describe both the pitch and volume of a sound and be able to distinguish between them. Teachers may allow students to touch various vibrating, sound-producing objects (such as tuning forks, drums, and stringed instruments) to demonstrate the relationship between an object's vibration and the sound it generates. Faster vibrations lead to higher pitches of sound. Students may enjoy hearing the tones produced by different musical instruments as they identify the vibrating sources of those sounds.

STANDARD SET 2. Life Sciences

Students learn that plants and animals have life cycles that are typical of their species. Students also begin to develop simple notions of inherited characteristics, variation within a species, and environmentally induced changes. Although the concepts are discussed at a simple level in grade two, they form a foundation for understanding the concepts of genetics, evolution, and ecology in later grade levels.

2. Plants and animals have predictable life cycles. As a basis for understanding this concept:

a. *Students know* that organisms reproduce offspring of their own kind and that the offspring resemble their parents and one another.

At one level the characteristics of a species are generally consistent from generation to generation. Dogs always give birth to puppies, and oak trees always drop acorns that grow into new oak trees. Offspring inherit genes from their biological parents with the result that they resemble their parents and each other. However, even among siblings, there is individual variation in both appearance and behavior. Some individual variation is due to genes that are inherited from each parent, as students will learn in later grade levels, and some is due to environmental influences.

2. b. *Students know* the sequential stages of life cycles are different for different animals, such as butterflies, frogs, and mice.

The life cycles of some insects consist of egg, larval, pupal, and adult stages. Many organisms undergo molting processes during the larval stage or the adult stage. This phenomenon is typical of species that have tough external skeletons (e.g., grasshoppers, crabs). Using mealworms (obtainable from many pet stores and kept in plastic containers with bran meal) is a good way for students to watch the life cycle of grain beetles over a period of a few weeks. The life cycles of those insects can be slowed down by placing the containers in the refrigerator at night and over weekends. Mealworms molt as they grow during their larval stages, and the casings can be easily recovered for study. Frogs and many other amphibians also undergo a type of metamorphosis, but those changes unfold gradually. Mammals bear live young that resemble, to a great extent, their adult forms.

2. c. *Students know* many characteristics of an organism are inherited from the parents. Some characteristics are caused or influenced by the environment.

This standard refines the understanding of Standard 2.a and prepares students for Standards 2.d and 2.e. As previously noted students must understand the concept of inheritance. Many characteristics of an individual organism are defined by the genes inherited from the biological parents. Other characteristics are strongly influenced by the environment or may be caused entirely by the environment.

2. d. *Students know* there is variation among individuals of one kind within a population.

Offspring may generally look like their parents and each other but may still vary in such aspects as color, size, or behavior. Within a broader population the extent of variation may be greater still. This standard should be discussed in the context of

the previous standard as variation is a function of both genetics and environmental influences.

2. e. *Students know* light, gravity, touch, or environmental stress can affect the germination, growth, and development of plants.

It is relatively easy to change the appearance or growth patterns of plants by changing the conditions of growth. Discussion of this standard can be tied to the discussion of the previous two standards. Roots typically grow downward in response to gravity. Stems and leaves grow upward or sideways to seek sunlight or an artificial light source. Environmental stress resulting from inadequate light, lack of nutrients, or the wrong amount of water impedes or halts the growth of plants.

Students may learn about plant germination and growth by planting seeds and observing their development. The effects of environmental factors (e.g., the amount of water and light, types of soil) can be readily studied. Students can make a root change the direction of its growth by mounting the germinating seeds between wet paper towels, placing the towels on a vertical sheet, and turning the sheet after several days to make the root respond to the new perception of "down." This experiment is evidence that plant growth responds to the downward pull of gravity. Students can also study how plants grow toward light over a period of weeks and turn many of their leaves to face the sun over the course of a day. To observe the effects of environmental stress, students can vary the light, temperature, soil composition, and amount of water that groups of the same kind of seed receive. Students may have already studied and grown plants in grade one, so it is important that in grade two they study plants at a deeper level.

2. f. *Students know* flowers and fruits are associated with reproduction in plants.

Plant germination and reproduction are related to the structure and function of seeds, flowers, and fruits. Although students may learn the idea entirely from stories and discussions, students can also take apart some large flowers to learn about plant reproductive structures. The use of magnifying glasses or simple microscopes will assist with observations. Inside the seed coat is the new plant embryo surrounded by food that is used during early growth and development. Students may find seeds inside juice oranges and apples and inside pea pods and ears of corn. Some common garden plants have extremely poisonous parts; therefore, the teacher should ensure that only safe plant materials are studied. Teachers should also be aware of student allergies.

STANDARD SET 3. Earth Sciences

The focus of earth sciences in grade two is on the composition, processes, and materials of Earth's crust. The term *weathering* is introduced as a process that leads to breaking rocks into smaller pieces. The interaction between the atmosphere and the upper surface of Earth's crust is the major source of weathering. Studying the relationship between weathering and soil formation, students learn that soil has an important effect on the growth and survival of plants. They also learn how soil is formed and about its constituent properties.

The concept of *geologic time* and the study of fossils are introduced. Students are asked to think abstractly about events that took place in Earth's ancient, geologic past. They will learn that Earth has not always looked the same as it does today. Teachers should present some of the evidence (particularly from fossils) that scientists use to "observe" what Earth was like in the geologic past. Students should be able to discuss and identify the origin of things they use in their everyday lives. Natural resources include rocks, minerals, water, plants, and soil. Understanding those ideas serves as a foundation for the study of earth sciences in later grade levels when students learn more about natural resources, including the identification of conservation techniques.

3. Earth is made of materials that have distinct properties and provide resources for human activities. As the basis for understanding this concept:

a. *Students know* how to compare the physical properties of different kinds of rocks and know that rock is composed of different combinations of minerals.

Students should know the physical properties (e.g., hardness, color, and luster) of a few of the most common minerals and be able to compare them. Students can compare rocks that are about the same size (volume) and note that some are heavier than others. They can also compare a few of the most common rocks. Students should conclude that rocks are composed of different combinations of minerals. They should know some simple techniques for making comparisons. It may be helpful to provide students with a set of common rocks formed from minerals (e.g., quartz, feldspar, mica, hornblende). Coarse-grained rocks (e.g., granite, gabbro, diorite) allow students to see individual mineral grains. The use of magnifying glasses or simple microscopes can help students to sort and classify the rocks according to their constituent minerals.

3. b. *Students know* smaller rocks come from the breakage and weathering of larger rocks.

Through the process of weathering (interaction between the atmosphere and Earth's surface), large rocks break down into smaller rocks. Rocks and minerals reduced by weathering to a very small size eventually turn into soil. Weathering may be a physical or chemical process. Physical weathering occurs when big rocks break down from the repeated freezing and thawing of water in cracks or when rocks are wedged apart by root growth. Rocks may also be chemically weathered through reactions with constituents of the atmosphere.

3. c. *Students know* that soil is made partly from weathered rock and partly from organic materials and that soils differ in their color, texture, capacity to retain water, and ability to support the growth of many kinds of plants.

This standard looks at soil as a whole and calls upon students to examine organic soil constituents in addition to weathered rock. Various combinations of weathered rock and organic material are reflected in soil properties, such as color, texture, capacity to retain water, and fertility. Organic materials, such as rotting, dead leaves and twigs as well as animal remains, add to the results of weathering. Burrowing mammals, such as gophers, and worm activity are responsible for mixing the soil. The types of both weathered material and organic remains that are mixed together and the proportions of the mixed constituents affect the properties of the soil. Dark soils often contain organic material, and red soils often derive from rocks and minerals rich in iron. Soil fertility depends more on the organic material than on the weathered rock contained in the soil. Decaying organic materials act to hold moisture in a spongelike manner and return nutrients to the soil.

3. d. *Students know* that fossils provide evidence about the plants and animals that lived long ago and that scientists learn about the past history of Earth by studying fossils.

A fossil is a physical record of life that lived in the geologic past. The study of fossils provides an opportunity for students to investigate plants and animals that lived long ago. Scientists compare plant impressions and the footprints and skeletons of dinosaurs to the characteristics of modern plants and animals. This study yields clues about the environments in which ancient organisms once lived. Geologists apply the concept of *uniformitarianism* as they try to reconstruct ancient geologic environments. The present is a key to the past if one assumes slow, uniform, and sequential changes have led to present conditions.

Teachers may be able to obtain a small collection of fossils or manufactured copies of fossils from local libraries, museums, science centers, or universities and supplement the collection with pictures of fossils found in books. By using fossils or pictures of fossils, students can try to reconstruct what animals and plants might

have looked like when alive. For example, fossil leaves are often black, but were they black when they were alive? Students may report their results orally or in written form, presenting their drawings as support for their conclusions.

3. e. *Students know* rock, water, plants, and soil provide many resources, including food, fuel, and building materials, that humans use.

Resources to meet many human needs, such as food, clothing, fuel, and shelter, originate from rocks, water, plants, and soil. Students should understand the relationship between manufactured materials and the natural resources from which they originate. For example, humans use the same weathered rocks that serve as a source material for soil as a resource for manufacturing building materials. Soil supports plant growth, and plants supply food for humans and for some of the animals that humans eat. Plants also supply fuel and building materials. Students should be able to name and identify the origin of the resources of some of the things they use as food, clothing, and shelter.

STANDARD SET 4. Investigation and Experimentation

The power of science is its ability to predict what will happen on the basis of concepts, principles, and theories related to the natural world. In grade two students can observe patterns associated with changes in objects and events. Under similar conditions students can use these patterns to make simple predictions. Teachers should not confuse predictions with hypotheses, which will be introduced in grade six. Measurements in science are always associated with units, and this idea is an important lesson for students to learn as they measure and record. Students should learn to measure length in meters and centimeters, weight (mass) in grams and kilograms, volume in liters and milliliters, and temperature in degrees Celsius. Students should also learn that scientists use tools to extend their powers of observation. Simple magnifiers and microscopes can be used to reveal exciting and sometimes surprising microstructures and properties of common objects, such as sand and cloth. Making careful sketches of what is observed under the magnifier is an important method by which students can communicate their observations.

4. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

a. Make predictions based on observed patterns and not random guessing.

Grade Two

b. Measure length, weight, temperature, and liquid volume with appropriate tools and express those measurements in standard metric system units.

c. Compare and sort common objects according to two or more physical attributes (e.g., color, shape, texture, size, weight).

d. Write or draw descriptions of a sequence of steps, events, and observations.

e. Construct bar graphs to record data, using appropriately labeled axes.

f. Use magnifiers or microscopes to observe and draw descriptions of small objects or small features of objects.

g. Follow oral instructions for a scientific investigation.

Grade Three Science Content Standards

Students in grade three are introduced to some of the most fundamental patterns in nature and should be taught that science makes the world understandable. For example, by observing that the stars appear fixed in relation to one another, one can identify five planets in motion against the starry background. Students in grade three begin to build a foundation for understanding the structure of matter and forces of interaction. They will study the properties of light and gain an appreciation for how light affects the perception of direction, shadow, and color. Students in grade three will also extend their knowledge of ecology by learning about different environments, such as oceans, deserts, tundra, forests, grasslands, and wetlands, and the types of organisms adapted to live in each.

The curriculum and instruction offered in grade three enable students to read materials independently with literal and inferential comprehension and to support answers to questions about the material by drawing on background knowledge and details from the text. Instruction in information literacy that incorporates library resources will help students become skilled in locating information in texts by using titles, tables of contents, chapter headings, glossaries, and indexes. The science standards complement the mathematics standards by asking students to predict future events on the basis of observed patterns and not by random guessing.

STANDARD SET 1. Physical Sciences (Energy and Matter)

The discussion of energy and matter in grade three is at a simple level, but it sets a foundation for further study in later grade levels. Students learn that energy may be stored in various ways and that both living organisms and machines convert stored energy into heat and motion. Matter will also be studied in more detail than at the previous grade levels. Atoms will be introduced as the smallest component of the elements that compose all matter. Students will learn that there are different kinds of atoms and that their names and symbols are displayed on the periodic table of the elements. This standard set will prepare the students for a more detailed treatment of the properties of the elements and their combinations in grade five.

1. Energy and matter have multiple forms and can be changed from one form to another. As a basis for understanding this concept:

a. *Students know* energy comes from the Sun to Earth in the form of light.

Energy is a physical attribute capable of causing changes in material objects. This concept is one of the more important ones in science. At a simple level, and

certainly for the treatment of the subject in grade three, energy is the ability to do work; to make things move, stretch, or grow; or to cause physical and chemical changes. Throughout the study of science, many more forms of energy and their effects will become evident. Students in grade three should understand that Earth's major source of energy is the Sun and that the Sun's energy is seen as light and felt as heat. It is important for students to realize that although light and heat are not exactly the same, both are forms of energy.

1. b. *Students know* sources of stored energy take many forms, such as food, fuel, and batteries.

Students should understand that the energy stored in food, fuel, and batteries can be released to create useful motion, light, and heat. For example, students may study the components of a flashlight and leave it on until the light goes out to emphasize that batteries store a limited amount of energy. Matches and candles are cold before lighting; but when burned, their stored energy is released in the form of light and heat. Students should be taught that they eat food in order to use its stored energy to make it possible for them to grow, maintain their warm body temperature, and be able to work and play. Teachers should note that all those forms of stored energy are contained in chemical substances and released through chemical changes.

1. c. *Students know* machines and living things convert stored energy to motion and heat.

This standard expands concepts introduced in earlier grades. The way in which machines and living things take different sources of energy and produce useful heat and motion should be examined in greater detail. An automobile engine releases the chemical energy stored in gasoline (and air) and uses it to turn the wheels and move the vehicle. Some students may be familiar with wind-up toys and will be able to understand that the potential energy stored in springs is used to turn the gears that activate the toy. Similarly, the energy stored in natural gas is converted to heat in a gas stove, oven, or furnace. Students learn that food is broken down into smaller components; some components are carried to the muscles, where the energy stored is released as movement and as heat, keeping the human body warm.

1. d. *Students know* energy can be carried from one place to another by waves, such as water waves and sound waves, by electric current, and by moving objects.

Energy movement or transfer should be discussed in terms of moving objects (e.g., thrown balls), waves (e.g., light, sound, seismic or earthquake waves, and ocean waves), and electricity (charges passing through a wire). The key point in this

standard is that energy is carried in those forms and transferred from one place to another. Simple toys that demonstrate transfer of motion to another object are good examples of this principle and form the foundation for understanding the conservation of energy. Energy of motion is transferred into heat through friction (such as when students rub their hands together rapidly and feel the heat generated by the rubbing motion).

Students can also study how waves transfer energy from one place to another through a medium (water or air), with no net motion or flow of matter. Students can demonstrate this principle by creating waves in a tub of water that contains materials (e.g., cork stoppers or small balls) floating on the water. Energy is required to start the wave at one end and is then transferred to the objects in the water, generating a bobbing motion. The students should note that this action can be accomplished without any net transfer of water from one end to the other. They should observe that waves make floating objects bob up and down and back and forth, but the objects stay in essentially the same position as they were in before the waves were generated.

Sound is made by vibrating objects and is carried in compression waves through the air. Sound can create vibrations in a distant second object (such as an eardrum) without direct physical contact between the two objects.

The evidence for electrical energy transfer surrounds students in their everyday lives. Electrical energy comes from power plants that may use fossil fuels, water, wind, or nuclear power. The key idea is that electrical energy has a source, is carried in wires as electricity, and is converted to more easily recognized forms of energy (such as heat, light, and motion).

1. e. *Students know* matter has three forms: solid, liquid, and gas.

Students in grade three must understand that matter is a substance that occupies space and may assume the form of a solid, liquid, or gas. Students should view pictures and read articles about lava and molten steel to make the point that most substances can turn to liquid when heated to a high enough temperature. Likewise, a gas can turn to a solid if sufficiently cooled. For example, carbon dioxide, a gas at room temperature, can be frozen into dry ice.

1. f. *Students know* evaporation and melting are changes that occur when the objects are heated.

This standard is an extension of what students will have learned about water in kindergarten and grade one. New to them is the generalization that melting and evaporation are processes that may occur when substances other than water are heated. Books and videos from the school library that show the process of making iron and steel may be helpful in providing instruction on this standard.

1. g. *Students know* that when two or more substances are combined, a new substance may be formed with properties that are different from those of the original materials.

This standard introduces the idea that pure substances have a fundamental character that is necessary in order to distinguish chemical changes from physical changes. Students are asked to build on some concepts that were introduced in earlier grades concerning changes in state and properties that may occur when two substances are mixed and react. Some students may begin to realize that there is a difference between mixtures and pure substances. The focus is on the new and different properties that are formed when two or more substances are mixed. The chemical reaction that occurs between baking soda and vinegar, producing carbon dioxide (and sodium acetate and water), is one of several simple reactions that may be used to illustrate this difference. Teachers can also use the burning of a candle to demonstrate this concept. The products with very different properties are the carbon dioxide gas and the soot produced and the heat and light released. Water vapor, also formed by burning a candle, may be observed as condensation on a cool object held above the candle.

1. h. *Students know* all matter is made of small particles called atoms, too small to see with the naked eye.

The important idea to convey is that all familiar substances are made of *atoms,* the term for the smallest particles of matter that retain the properties of the elements. To understand atoms, students must first be introduced to the idea that *matter* is the general name given to anything that has mass and occupies space. They should then be taught that matter comprises all solids, liquids, and even invisible gases. Just as a brick wall consists of many individual bricks, all matter consists of smaller bits that combine to make up what is seen. Students can discover this principle by looking through an inexpensive 30-power (30x) microscope to discover that the apparently solid colors on the cover of magazines actually consist of repeated patterns of colored dots.

Atoms are so tiny that detection requires techniques that go beyond the power of conventional microscopes. The following imaginary experiment may be helpful in understanding the basic concept of the atom. If a student were to take an object made of a pure element, such as a piece of aluminum foil, and cut it in half, both halves are still aluminum. If each of these pieces is then cut in half a second, third, fourth, and fifth time, the pieces become progressively smaller but are still aluminum. Is it possible to keep cutting the pieces in half forever and still have a piece of aluminum? How small must a piece be so that at the next cut it will no longer be aluminum? In pondering this question, early philosophers concluded that there must be a very small but indivisible piece of matter that still has the properties of aluminum or any other element. They named these smallest pieces *atoms.*

1. i. *Students know* people once thought that earth, wind, fire, and water were the basic elements that made up all matter. Science experiments show that there are more than 100 different types of atoms, which are presented on the periodic table of the elements.

In ancient times people believed that everything was made of combinations of just four elements: earth, air, fire, and water. This belief is understandable when one observes a log burn to become ash, fire, and hot gases, some of which condense into water. The Greeks, however, conjectured that matter is made of tiny particles. Today this belief is known to be true, and those particles are called *atoms.* More than 100 different types of elements are displayed on the periodic table of the elements. Students in grade three should know a chart exists that displays the names and symbols of known elements and other information.

The names of elements may fascinate students. Many elements may be familiar to the students (e.g., gold, silver, copper, iron, oxygen), but some will not be familiar. Students may enjoy finding names of familiar elements on the table. The custom of science is that discoverers have the right to name their elements. Some elements, such as einsteinium and seaborgium, are named after famous scientists (Albert Einstein and Glenn Seaborg) whose personal lives are the basis of interesting stories. Students may be fascinated to learn that one element is named californium and one is named for the city of Berkeley: berkelium. An important concept for students to know is that any substance not listed on the periodic table comprises a combination of different types of atoms (elements) that are listed. Living organisms, for example, are mostly made up of carbon, oxygen, nitrogen, and hydrogen atoms.

STANDARD SET 2. Physical Sciences (Light)

Light, like heat, is a form of energy. Standard Set 2 calls for students to know some of the properties of light but does not require them to understand light as energy in a waveform. They should know that light travels in a straight line away from its source and that the color of an object is affected by the color of light that strikes it.

2. Light has a source and travels in a direction. As a basis for understanding this concept:

a. *Students know* sunlight can be blocked to create shadows.

Teachers may draw an analogy between an opaque object casting a shadow in sunlight and the dry place created when an umbrella blocks the fall of raindrops. The energy of sunlight is absorbed by the opaque object and is prevented from passing through to the ground. Students should be encouraged to experiment with shadows and to think about the source and direction of the light. They can cut

cardboard into different shapes, compare the size and shape of the cardboard with the size and shape of its shadow, and notice whether the edges of the shadows are sharp or fuzzy.

2. b. *Students know* light is reflected from mirrors and other surfaces.

Light reflected from a mirror or other surface changes direction by reflection and then continues to travel in a straight line. To demonstrate reflection and note the path of a reflected beam of light, the teacher or a group of students can use chalk dust or a water mist to help trace the path of the light beam in a darkened room.

2. c. *Students know* the color of light striking an object affects the way the object is seen.

Two factors determine the color of an object: the color of the light illuminating the object and the interaction of the light with the object; for example, which colors are absorbed and which are reflected. Students can see this principle for themselves by being asked to describe an object's color viewed under lights of different colors. Because sunlight contains all the colors of the rainbow, light sources of different colors can be created by passing sunlight through colored cellophane. This principle can also be demonstrated by using colored light bulbs. To explore the principle in the standard, students may observe that a white object will be seen as the color of the light that illuminates it. For example, if a white piece of paper is seen under red lights, it appears to be a red piece of paper.

2. d. *Students know* an object is seen when light traveling from the object enters the eye.

Light is a form of energy to which the eye is sensitive. An object can be seen because the light that travels from the object enters and interacts with the eye. If opaque material comes between the eye and an object being viewed, the opaque material blocks the light and the object disappears from view, demonstrating that light travels in a straight line.

STANDARD SET 3. Life Sciences

The life sciences standards in grade three continue to develop students' concepts of ecology and evolution by relating adaptation to the survival and fitness of the organism. Although natural selection is not formally discussed at this grade level, the foundation is set for teaching that principle in later grade levels. A significant effort is made to enhance students' knowledge of the types of plants and animals in different environments as this understanding becomes an important base of knowledge. These standards challenge students to consider the effects of environmental changes on organisms. The concept of extinction

is introduced, and organisms in the fossil record are compared to contemporary organisms.

3. Adaptations in physical structure or behavior may improve an organism's chance for survival. As a basis for understanding this concept:

a. *Students know* plants and animals have structures that serve different functions in growth, survival, and reproduction.

Students have learned about the roots and leaves of plants in grade one and the functions of flowers and fruit in grade two. Many other external structures of plants and animals (e.g., cactus thorn, porcupine quill, crab shell, bear claw, and kangaroo pouch) serve important functions, and students in grade three will recognize many common examples through reading and observing examples from nature. This standard can be taught in the context of the one that follows and can serve as the basis for extended study and discussion.

3. b. *Students know* examples of diverse life forms in different environments, such as oceans, deserts, tundra, forests, grasslands, and wetlands.

The organisms that live in oceans, deserts, tundras, forests, grasslands, and wetlands are different from one another because their environments are different. For example, animals with thick fur are able to survive a cold habitat. Gills allow fish to obtain oxygen from water, whereas lungs allow mammals to obtain oxygen from the atmosphere. Desert plants and animals have adapted by conserving the small amount of water they require. The thick, waxy leaves of some plants prevent water loss. Many desert animals are nocturnal and search for food during the cool of night.

Students should be taught about Earth's different habitats or *biomes* and be able to describe the characteristics of some of the plants and animals living in each. Students should be encouraged to locate information in nonfiction books and other library resources and be able to describe how living organisms are adapted for survival in their particular biome.

3. c. *Students know* living things cause changes in the environment in which they live: some of these changes are detrimental to the organism or other organisms, and some are beneficial.

Living organisms, including humans, inevitably cause changes (some minor and some major) in the environment as the organisms compete for food, shelter, light, and water. Those changes are different from external changes, such as a fire started by lightning or flooding related to excessive rainfall. When some organisms become more or less successful in their quest for survival, the environmental balance changes and so does the environment. For example, beavers build dams that block streams, forming small lakes in which they can then reside. This activity is

beneficial to plants and animals that prefer to live in still water, but it is detrimental to plants and animals that are used to living in an open stream. It is also detrimental to large trees as they are cut and become material for the beaver. Trees affect the environment by blocking the sunlight; consequently, the felling of a large tree by a beaver may benefit smaller plants and shrubs that can now grow in its place. These examples are some of the types of environmental relationships studied by ecologists.

3. d. *Students know* when the environment changes, some plants and animals survive and reproduce; others die or move to new locations.

Many plants and animals have specialized structures that allow them to survive and reproduce in the environment in which they live. Consequently, they may be adversely affected by environmental changes. For example, many plants and animals not suited to desert conditions will die if their environment becomes dry and desertlike for an extended period of time. Plants and animals establish a balance with one another in their shared environment. Consequently, environmental changes that affect one or more plants or animals in a given biome may eventually affect all living organisms in that biome. Animals may move, and seeds may be blown or carried to new, more favorable locations.

3. e. *Students know* that some kinds of organisms that once lived on Earth have completely disappeared and that some of those resembled others that are alive today.

When an environment changes more quickly than a species of animal or plant can adapt, that species may become extinct. Fossils provide numerous examples of extinct plants and animals. By studying the characteristics of fossils, students can see that some extinct animals resemble animals that are alive today and that others are quite different.

Students can relate modern animal remains to the environments from which they came and then they can apply the same types of observations and reasoning to determine the kind of environment that may have supported the fossilized animals and plants.

STANDARD SET 4. Earth Sciences

Earth sciences standards in grade three center on the concept that objects in the sky move in regular and predictable patterns. It is important that students know and are familiar with the patterns and movements of the Sun, Moon, and stars, both as those bodies actually move and as they appear to move when viewed from Earth. Seasonal changes correlate with changes in both the amount of daily sunlight and the position of the Sun in the sky. Seasonal changes are caused by the tilt of Earth's axis of rotation and the position of Earth relative to the Sun. Students will also learn about the relationships between

the phases of the Moon and the changes in the positions of the Sun and Moon. Using models and telescopes may help students grasp the concepts presented in the standards.

4. Objects in the sky move in regular and predictable patterns. As a basis for understanding this concept:

a. *Students know* the patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.

The relative position of stars with respect to each other in the night sky is fixed. The apparent motion of the stars through the night sky is a function of Earth turning on its own axis. Starlike objects do move across the fixed pattern of stars in the night sky, but those "stars" are really planets. Stars appear stationary relative to one another because they are far outside the solar system. The positions of stars appear to change each season from a particular point of view on Earth because that point will face progressively different parts of the universe at night. The stars that are visible in the summer nighttime sky would be visible in the winter daytime sky if they were bright enough to outshine the Sun.

4. b. *Students know* the way in which the Moon's appearance changes during the four-week lunar cycle.

Students should be taught to observe the phases of the Moon; recognize the pattern of changes; and know such terms as the *full, quarter, waxing, waning,* and *crescent Moon.* The reason for this pattern of changes may then be explored.

One side of the Moon is always in sunlight (except in the case of an eclipse). How much of the sunlit surface of the Moon will be visible from Earth depends on the relative positions of Earth, the Moon, and the Sun. Earth and the Moon continuously cycle through changes in their positions relative to the Sun; therefore, the Moon will go through phases from "new" to "full" depending on how much of its lighted surface is visible from Earth.

Models may help in the teaching of the standard. Students may be shown the rotation of Earth on its axis; how the day and night cycle works; and why the Moon, like the Sun, appears to rise and set. Students may also be shown Earth's position relative to the Sun, the Moon's position relative to Earth, and how Earth orbits the Sun once a year. Students can observe the actual position changes in the Moon and in the background star patterns at the same time each night, continuing their observations long enough to include a full lunar cycle. They can be shown how the motion of the Moon around Earth accounts for those observations.

4. c. *Students know* telescopes magnify the appearance of some distant objects in the sky, including the Moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than the number that can be seen by the unaided eye.

Students are often startled the first time they look at details of the Moon through a telescope or even through high-quality binoculars. They quickly come to appreciate how those instruments facilitate the study of very distant objects. With the help of a telescope or very high-powered binoculars, students can see the rings of Saturn and some of the details of other planets. Students must never be permitted to look directly or stare at the Sun with the naked eye through binoculars, telescopes, or any other optical instruments. There are many pictures taken by powerful telescopes of planets, stars, and galaxies that students should have the opportunity to study in books.

4. d. *Students know* that Earth is one of several planets that orbit the Sun and that the Moon orbits Earth.

The patterns of the stars stay the same relative to one another although they appear to move because of the rotation of Earth. Several starlike objects move across the sky's star patterns. They are planets that shine by light reflected from the Sun. Five planets can be seen without the aid of a telescope: Mercury, Venus, Mars, Jupiter, and Saturn. Three can be seen only with the aid of a telescope: Uranus, Neptune, and Pluto. Earth is also a planet and moves about the Sun in a path (orbit) that is similar to that of the other planets. Nine planets are in the solar system. The Moon orbits Earth. Because Earth itself is a planet, measuring the orbits of other planets is a complex process. The process is so complex that scientists took a long time to figure out the different spatial relationships between the Moon, Earth, other planets, and the Sun.

4. e. *Students know* the position of the Sun in the sky changes during the course of the day and from season to season.

During a single day the rotation of Earth causes the position of the Sun to change on the horizon. It may be helpful for students to keep track of the Sun's position and watch how shadows lengthen rapidly as sunset approaches. From season to season the length of day and the angle of the Sun vary. Students should know that they live in the Northern Hemisphere, where the Sun at noon is lower and to the south in the sky in the winter and more directly overhead in the summer. Shorter or longer days and more or less direct sunlight characterize the seasons. The angle of the Sun in the sky at noon and the length of the day vary throughout the year because Earth's axis is tilted in comparison to the plane of its orbit.

STANDARD SET 5. Investigation and Experimentation

Children should be taught to make careful measurements, but they also need to learn that some errors in measurement are unavoidable. Sometimes errors arise through carelessness, misuse of measurement instruments, or recording mistakes. These human errors can be minimized by instruction and practice in measuring carefully and properly and by double (or triple) checking of measurements. Even then errors may be introduced because of limitations in the precision of the instruments used to make the measurements. Students should be taught how to make the most precise measurements possible with the tools available. They should also repeat their measurements several times. Sometimes they will obtain results that are different each time. If those differences are significant, students should examine their measurement methods to see whether an obvious error occurred.

Students can begin to make predictions based on observations, prior knowledge, and logic. Predictions should not be confused with random guesses. Students should know that their predictions must be verified by experiments and the analysis of data gathered from careful measurements.

5. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- **a.** Repeat observations to improve accuracy and know that the results of similar scientific investigations seldom turn out exactly the same because of differences in the things being investigated, methods being used, or uncertainty in the observation.
- **b.** Differentiate evidence from opinion and know that scientists do not rely on claims or conclusions unless they are backed by observations that can be confirmed.
- **c.** Use numerical data in describing and comparing objects, events, and measurements.
- **d.** Predict the outcome of a simple investigation and compare the result with the prediction.
- **e.** Collect data in an investigation and analyze those data to develop a logical conclusion.

Grade Four Science Content Standards

Students in grade four will learn to design and build simple electrical circuits and experiment with components such as wires, batteries, and bulbs. They will learn how to make a simple electromagnet and how electromagnets work in simple devices. They will observe that electrically charged objects may either attract or repel one another and that electrical energy can be converted into heat, light, and motion. Students in grade four expand their knowledge of food chains and food webs to include not only the producers and consumers they have previously discussed but also the decomposers of plant and animal remains, such as insects, fungi, and bacteria. They will also learn about other ecological relationships, such as animals using plants for shelter or nesting and plants using animals for pollination and seed dispersal. Students in grade four study rocks, minerals, and the processes of erosion. They also study the processes of weathering and erosion as a way of leading into the study of the formation of sedimentary rocks.

Students in grade four learn to formulate and justify predictions based on cause-and-effect relationships, differentiate observation from inference, and conduct multiple trials to test their predictions. In collecting data during investigative activities, they learn to follow a written set of instructions and continue to build their skills in expressing measurements in metric system units. They will analyze problems by identifying relationships, distinguishing relevant from irrelevant information, sequencing and prioritizing information, and observing patterns, all of which support the *Mathematics Content Standards.*[2] They should conduct scientific investigations and communicate their findings in writing.

STANDARD SET 1. Physical Sciences

Students entering grade four have already had some exposure to the subjects of electricity and magnetism, but these standards are a systematic effort to develop the principles of each and show how they are interrelated. The standards in grade four provide a simple understanding of electricity and magnetism and some applications in everyday life; they help to develop a foundation for further learning in high school.

1. Electricity and magnetism are related effects that have many useful applications in everyday life. As a basis for understanding this concept:

a. *Students know* how to design and build simple series and parallel circuits by using components such as wires, batteries, and bulbs.

Students should design and build series and parallel circuits with wires, batteries, and bulbs. Many science books describe simple experiments for constructing

series and parallel circuits. In series circuits one wire loop connects all the components, so current flows sequentially through the components in the one loop. In parallel circuits several loops of wires connect the components. A simple series circuit consists of two or three light bulbs wired together with a battery in a single loop. If the filament of one bulb breaks (or one bulb is removed from its socket), the single-circuit loop is broken and all the lights go out. Teachers may make a parallel circuit by extending two wires, parallel to each other, from the poles of a battery. Then they connect two or three bulbs, individually, across the parallel wires. If one of the bulb filaments is broken, the other bulbs still remain lit.

The series circuit is like a circular road that has no intersection; a series circuit has only a single path, and all components must carry the same current. The amount of current that can flow through a circuit depends on resistance. The lower the circuit's resistance, the higher the current that can flow through it. Overall resistance in a series circuit is the sum of the resistances of its individual components. In parallel circuits there are intersections and alternate pathways for the current, and each pathway may have different components on it. These alternate pathways split the current between them, depending on their electrical resistance (again, lower resistance along a pathway allows higher current). An alternate pathway with extremely low resistance, such as a wire with no components on it, is sometimes called a *short circuit.* Short circuits can prevent the rest of the circuit from operating properly and be dangerous because the short-circuiting wire may become very hot.

1. b. *Students know* how to build a simple compass and use it to detect magnetic effects, including Earth's magnetic field.

Students should know that all magnets have two poles: north and south. They should have already experienced the attraction of the north and south poles and the repulsion of north-to-north and south-to-south in their science studies in grade two. They should have noted that the repulsion or attraction is stronger when the poles are close and weaker when the poles are further from each other. Any magnet suspended so that it can turn freely will align with Earth's magnetic field, provided that the attraction is not overwhelmed by a stronger local field. A compass needle will detect and respond to the presence of magnets.

Students can build a simple compass by rubbing a craft needle (blunt-tip) on a strong permanent magnet to magnetize it. (***Caution:*** Students should be closely supervised to avoid injury.) The magnetized needle may then be placed on a piece of cork or sponge floating in a small bowl of water. The same effect may be observed by using a small (one centimeter long) bar magnet resting on a floating piece of cork. The magnet or needle will float around until one end points generally toward Earth's magnetic north pole (which is slightly off from true north). The north end (pole) of a magnet refers to its attraction to Earth's magnetic north pole. Ring magnets may be suspended from a thread, and the axis of the hole in the magnet will also point north and south. If the students use a commercial compass, they can confirm the orientation of their experimental compass. When working with compasses, teachers need to check that a set of compasses all point in the same direction.

Large amounts of steel (such as the supporting beams of modern buildings) and operating electronic devices (such as television sets and computers) may distort the effects of Earth's magnetic field and cause an inaccurate compass reading.

1. c. *Students know* electric currents produce magnetic fields and know how to build a simple electromagnet.

Once students understand that electric currents produce magnetic fields, they can apply this knowledge to the construction of a simple electromagnet made by wrapping a half-meter length of insulated wire around a large iron nail or iron rod and connecting the ends of the wire to a battery. When an electric current from the battery flows through the wire, the iron bar is magnetized. Students can use a compass to prove that, like permanent magnets, their electromagnet has two poles. If the orientation of the battery is reversed, the poles of the magnet are reversed so that south becomes north and north becomes south. Students in grade four are unlikely to have sufficient knowledge to predict that this would happen, but in high school they will have an opportunity to understand the principles at a much deeper level.

1. d. *Students know* the role of electromagnets in the construction of electric motors, electric generators, and simple devices, such as doorbells and earphones.

This standard builds on the previous one by challenging students to become aware of the role of electromagnets in their surroundings at home and at school. They learn that electromagnets are important in the function of electric motors, generators, doorbells, and earphones. Electromagnets may be thought of as magnets that can be turned on and off. When an electromagnet is switched on, an adjacent iron magnet can be made to move; this type of electrically induced movement can be harnessed (e.g., to ring doorbells or vibrate a speaker element in a pair of headphones). Simple schemes for constructing the equivalent of a doorbell or an electric motor may be found in textbooks. Constructing such a device helps students realize that they are using the interaction of two magnetic fields: one from a coil (an electromagnet) and the other from a permanent magnet (or, in some schemes, another electromagnet).

One way to understand a motor is that the alternating attraction and repulsion of the two magnetic fields converts electrical energy into the energy of motion. In high school, students will learn that charges (electrons) flowing in wires that cross magnetic fields experience a force that explains the rotation in the motor. An electric generator acts like an electric motor operating in reverse to change the energy of motion into electrical energy.

To go further in understanding the workings of home appliances, students may consult books or multimedia references on how things work. Students should be warned not to dismantle electrical appliances at home. ***Note:*** Dismantling electrical devices to determine how they work may be dangerous because some devices can hold lethal charges for days or weeks.

1. e. *Students know* electrically charged objects attract or repel each other.

After scuffing their feet on a carpet on a dry day, students may have had the experience of "getting a shock" from touching a grounded object or another person. This experience is an example of *static electricity,* which is associated with the gain or loss of negative electric charges (electrons). The shock a student receives in the foregoing example is associated with equalizing the charges between objects and involves the movement of electrons. Attractive and repulsive forces are at play between charged objects; however, lightweight objects (such as balloons and scraps of paper) are typically needed to perceive these forces at work.

A negatively charged object will attract a positively charged object and repel another negatively charged one. Two positively charged objects will also repel each other. This phenomenon is analogous to the like poles of magnets repelling each other and the unlike poles attracting. A latex balloon may be used to demonstrate attraction. The balloon may be suspended from the ceiling by a thread and rubbed with a wool sock. The balloon and sock attract each other. The teacher may rub with a sock another balloon (attached to a stick by a 20- to 30-centimeter-long thread) next to the suspended balloon. The two balloons will repel each other. Balloons that have been "charged" in this way may also pick up little bits of paper (1 mm square) and attract strands of hair.

1. f. *Students know* that magnets have two poles (north and south) and that like poles repel each other while unlike poles attract each other.

An assortment of magnets of different sizes and shapes can be used to demonstrate this standard. Two or more donut-shaped magnets may be strung in different order on a pencil, and one magnet may be suspended in the air. Students can observe the bouncing effect that results from the repulsive force increasing as the magnets get closer. Refrigerator magnets are made of tiny strips of alternating north and south poles next to each other. They appear to just stick and never repel. However, by carefully sliding one refrigerator magnet over the other, one can perceive the alternate effects of repulsion and attraction.

1. g. *Students know* electrical energy can be converted to heat, light, and motion.

Electrical energy is partially converted to heat and light when it flows through wires because the wires resist this flow. For example, light and heat are produced when electricity flows through the filament of a light bulb. Electrical energy may also be converted to kinetic energy by the use of devices such as an electromagnet or an electric motor. The conversion of electrical energy to heat can be demon-- strated by feeling the warmth generated in the coil of an electromagnet when the circuit is completed. Common everyday experiences include incandescent light bulbs that are too hot to touch because most of the electrical energy is used to make

the filament hot. Students can also observe that when they light a bulb with a battery, converting electrical energy into light, the lit bulb becomes warm.

If the current flowing through a circuit is high, the wires need to be thick enough to carry the current without becoming too hot. Extension cords designed to be used for high-current appliances, such as space heaters and microwave ovens, are thicker than extension cords designed to be used for a desk lamp. In addition, household circuits are rated to carry only a limited amount of current. If too many electrical devices are plugged into a circuit at once, a problem that is often made worse by "outlet expanders," a house fire may result from overheating of the wires. A fire may also result if the insulation in a wire is frayed and two wires short-circuit. The purpose of fuses and circuit breakers in a house is to prevent overloading of circuits and overheating of wires. Demonstrations in the classroom should never be done by using household current; even a short-circuited battery can generate enough heat to burn students, so teachers must carefully choose and monitor laboratory demonstrations and experiments.

STANDARD SET 2. Life Sciences

Students in grade four have already learned about types of plants and animals that inhabit different biomes and will have a simple understanding of adaptation from studies in grades one and three. The standards in grade four help to refine students' understanding of ecological principles and prepare them to learn much more about the subject in grade six.

2. All organisms need energy and matter to live and grow. As a basis for understanding this concept:

a. *Students know* plants are the primary source of matter and energy entering most food chains.

A food chain is a representation of the orderly flow of matter and energy from organism to organism by consumption. Plants harness energy from the sun, herbivores eat plants, and carnivores eat herbivores. Solar energy therefore sustains herbivores and, indirectly, the carnivores that eat them; this is the important principle to be taught.

2. b. *Students know* producers and consumers (herbivores, carnivores, omnivores, and decomposers) are related in food chains and food webs and may compete with each other for resources in an ecosystem.

Students may recall from previous grade levels that animals eat plants or other animals. This standard extends the subject to a greater depth. Food chains and food webs represent the relationships between organisms (i.e., which organisms are consumed by which other organisms). Generally, food chains and food webs must

originate with a primary producer, such as a plant that is producing biomass. Herbivores and omnivores eat the plants; carnivores (secondary consumers) in turn eat the herbivores and omnivores. Decomposers consume plant and animal waste, a step that returns nutrients to the soil and begins the process again. Decomposers, such as fungi and bacteria, should be included at each level of the food web as they consume the remains and wastes of plants and animals.

2. c. *Students know* decomposers, including many fungi, insects, and microorganisms, recycle matter from dead plants and animals.

Plant and animal wastes, including their dead remains, provide food for decomposer organisms such as bacteria, insects, fungi, and earthworms. Decomposers are adept at breaking down and consuming waste materials and therefore complete the food chain, returning nutrients to the soil so that plants may thrive as producers. Bacteria and fungi also pass energy to other parts of a food web. Those microorganisms are themselves consumed by slightly larger organisms, such as worms and small insects, and those small consumers are food for larger animals, such as birds. Microorganisms and their biological ability to decompose matter may be observed in video or film productions using time-lapse photography. Molds grown on bread and fruit may be studied with the use of magnifying lenses; however, it is dangerous for a class to collect wild fungi, culture bacteria, or molds derived from soils or rotting meats.

STANDARD SET 3. Life Sciences

Students have learned in previous grades about the interactions of organisms in an ecosystem; this standard set develops the subject still further. The living and nonliving components are clearly distinguished, and the significant effects of invisible microorganisms are also discussed.

3. Living organisms depend on one another and on their environment for survival. As a basis for understanding this concept:

a. *Students know* ecosystems can be characterized by their living and nonliving components.

Each ecosystem is characterized by a set of living (biotic) and nonliving (abiotic) components that distinguish it from other ecosystems. For example, tropical rain forests, coral reefs, and deserts all have distinctly different biotic and abiotic components. This standard challenges students to be systematic in describing the components of an ecosystem and in identifying the characteristics of life.

3. b. *Students know* that in any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all.

This standard is partly an extension of the study of adaptive characteristics of plants and animals that students may have encountered in grade three. All living organisms have biological requirements for growth and survival and can live only in environments to which they are well adapted. If an environment changes in a way that is harmful to an organism, the organism may not be able to survive. Adaptation is a genetic process that takes many generations to be perceived, so a single individual cannot "adapt" to a change. For example, the thick, blubbery skin of whales is an evolutionary adaptation to cold water. This adaptation is different from the types of changes that help a single individual survive, such as a change in seasonal diet or coloration, which are properly called *accommodations.*

3. c. *Students know* many plants depend on animals for pollination and seed dispersal, and animals depend on plants for food and shelter.

The idea of plants and animals being mutually dependent was a topic of discussion in grade one. The concept can now be discussed at a much deeper level because students will have an emerging grasp of ecology and natural history. Many plants depend on bees, birds, and bats to pollinate their flowers. The resulting seeds may be scattered away from the parent plant by becoming entangled in the fur of animals. Other seedpods are moved and stored by animals in seed caches; some are consumed and deposited (still fertile) in animal wastes. The fruits of some plants are attractive food sources for animals. Plants often provide shelter for animals, hiding them from predators.

3. d. *Students know* that most microorganisms do not cause disease and that many are beneficial.

Microorganisms play a vital role in the environment. This standard helps students to look beyond the common misconceptions that bacteria are responsible only for diseases and that microorganisms are responsible only for decomposition. Some bacteria and single-celled organisms called *protists* are photosynthetic, and their contribution as primary producers of biomass in the ocean far exceeds that of the "visible" plants. Food chains and food webs may be based on bacteria and protists; therefore, a microscope will help students to observe microorganisms.

Growing cultures in the classroom provides students with opportunities to study bacteria and protists. A hay infusion is relatively safe to grow in a classroom. Within a few days students will be able to see numerous types of microorganisms through a microscope. Teachers and students should not culture soils and meat broths as some microorganisms can cause serious illness.

STANDARD SET 4. Earth Sciences (Rocks and Minerals)

Earth sciences standards in grade four are divided into three areas of study: rocks, minerals, and the processes of erosion. The topics extend what students have already learned in grade two and prepare them for a deeper level of understanding in grade six.

4. The properties of rocks and minerals reflect the processes that formed them. As a basis for understanding this concept:

a. *Students know* how to differentiate among igneous, sedimentary, and metamorphic rocks by referring to their properties and methods of formation (the rock cycle).

Rocks are usually made from combinations of different minerals and are identified from their composition and texture. Molten magma and lava cool and solidify to form igneous rocks. Metamorphic rocks form when a parent rock of any type is subjected to significant increases in pressure and temperature, short of melting. Sedimentary rock forms when rock is weathered, transported by agents of erosion, deposited as sediment, and then converted back into solid rock—a process called *lithification.* For classroom discussions it is best to begin with minerals and then progress to rocks. (See the next standard for a discussion of teaching about minerals.)

Students learn to sort rock specimens into groups of igneous, sedimentary, and metamorphic rocks. Students should learn to relate descriptions of rock mineral content and properties to the three rock groups. Rocks that are hard but show no layering are likely to be igneous rocks. Often they have interlocking crystalline textures. Rocks that are soft, particularly those with layers, are likely to be sedimentary rocks. They often have "fragmental" textures; they look like broken grains of older rocks cemented back together. Hard rocks that have their minerals lined up or arranged in uneven layers are likely to be metamorphic rocks. This description briefly depicts some of the most common rocks; however, there are many exceptions. Field guides to rocks and minerals may be checked out from the school library-media center and would be helpful to have for reference in the classroom.

4. b. *Students know* how to identify common rock-forming minerals (including quartz, calcite, feldspar, mica, and hornblende) and ore minerals by using a table of diagnostic properties.

Geologists describe and identify minerals according to a set of properties, such as hardness, cleavage, color, and streak. Hardness is determined by the Mohs hardness scale, which refers to materials' relative ability to scratch other materials or be scratched by them. Most earth sciences books contain tables of diagnostic mineral properties that can be used to assist students with sorting or classifying minerals.

The identification process requires matching the observed properties of a sample with those noted on a diagnostic table of properties. This standard focuses on only a few of the most common rock-forming minerals (e.g., quartz, calcite, feldspar, mica, hornblende) as well as some important ores, such as galena (lead) and hematite (iron). The colorful ores of copper may also be added to this list. Other resources, such as field guidebooks, computer programs, approved and preselected Internet sources, and resources from the school library, may help students identify mineral samples.

STANDARD SET 5. Earth Sciences (Waves, Wind, Water, and Ice)

The processes of weathering and erosion continually form the sediments that form new rocks as a part of the constant recycling of Earth's crust. Some changes on Earth's surface take place so slowly that they are hard for students to observe; others occur so rapidly that they may be frightening. Erosion and transportation are processes in which material is transported over short or long distances and may take place at different rates. Movement along faults may be slow or fast. Earth's surface may be built up slowly or erupt suddenly. Students tend to overemphasize the effectiveness of rapid processes because they are easy to identify, but the slow processes may ultimately have the greatest effect on the shape of Earth's surface.

5. Waves, wind, water, and ice shape and reshape Earth's land surface. As a basis for understanding this concept:

a. *Students know* some changes in the earth are due to slow processes, such as erosion, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.

Erosion may occur so slowly that careful measurements are necessary to establish that a change is taking place; however, landslides may take place very rapidly. Volcanoes can build with explosive speed and then be quiet for long periods. Breaks in Earth's crust, called *faults,* experience slow movement, called *creep,* and rapid movements that cause earthquakes.

5. b. *Students know* natural processes, including freezing and thawing and the growth of roots, cause rocks to break down into smaller pieces.

Chemical weathering occurs when atmospheric components (e.g., oxygen, carbon dioxide, and water) interact with Earth's surface materials and cause them to break apart or dissolve. Purely physical processes, such as alternate freezing and thawing of water, exfoliation, or abrasion, may also contribute to the weathering process. Plants may promote weathering as their roots expand in cracks to break rocks. Weathering results in the formation of soil or sediment.

To demonstrate the effects of freezing and thawing, teachers may use plastic bottles. Students can fill a soft plastic bottle with cold water. They make certain that

all the air is removed from the bottle before tightly capping it and placing it in a freezer. The expansion of water as it freezes will deform the bottle and possibly even split it.

5. c. *Students know* moving water erodes landforms, reshaping the land by taking it away from some places and depositing it as pebbles, sand, silt, and mud in other places (weathering, transport, and deposition).

Weathering produces pebbles, sand, silt, and mud. Erosion and transportation move the products of weathering from one place to another. As erosion transports the broken and dissolved products of weathering, it alters the shape of landforms. The most important agent of transportation is water. Water flowing in streams is energetic enough to pick up and carry silt, sand, pebbles, mud, or at flood stage even boulders. Flowing water reshapes the land by removing material from one place and depositing it in another.

STANDARD SET 6. Investigation and Experimentation

Students in grade four improve their ability to recognize the difference between evidence and opinion. They learn the difference between observation and the inference of some underlying cause or unseen action. Teachers will need carefully designed investigations and experiments that result in predictable student errors to teach the students the difference between observation and inference. Another important milestone is that students will learn to formulate cause-and-effect relationships and to connect predictions and results.

6. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

a. Differentiate observation from inference (interpretation) and know scientists' explanations come partly from what they observe and partly from how they interpret their observations.

b. Measure and estimate the weight, length, or volume of objects.

c. Formulate and justify predictions based on cause-and-effect relationships.

d. Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.

e. Construct and interpret graphs from measurements.

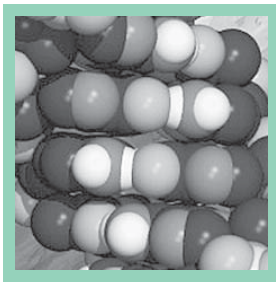
f. Follow a set of written instructions for a scientific investigation.

Grade Five Science Content Standards

Students in grade five will learn about chemical reactions and discover the special (and shared) properties of metallic elements. They will clearly distinguish between molecules and atoms and chemical compounds and mixtures and learn about the organization of atoms on the periodic table of the elements. They can then be shown how particular chemical reactions (e.g., photosynthesis and respiration) drive the physiological processes of living cells. They will add to what they have learned in previous grade levels about the external characteristics and adaptations of plants and animals and learn about some of the fundamental principles of physiology. They will learn about blood circulation and respiration in humans; digestion of food and collection and excretion of wastes in animals; the movement of water and minerals from the roots of plants to the leaves; and the transport of sugar generated during photosynthesis from the leaves to the other parts of the plant.

Students in grade five also study the hydrologic cycle (water cycle), the process by which water moves between the land and the oceans. They will learn how the hydrologic cycle influences the distribution of weather-related precipitation and, as a consequence, the types and rates of erosion. They will also study the solar system and learn that it contains asteroids and comets in addition to the Sun, nine planets, and moons. They will learn the composition of the Sun and the relationship between gravity and planetary orbits.

The *Science Content Standards* and *English–Language Arts Content Standards* are complementary so that the writing strategies will lay a foundation for good writing on science reports and informative oral science presentations.[3] The *Science Content Standards* and the *Mathematics Content Standards* also reinforce each other as students analyze, strategize, and solve problems, finding solutions to apply to new circumstances. Students in grade five will also develop testable questions and learn to plan their own investigations, selecting appropriate tools to make quantitative observations.



STANDARD SET 1. Physical Sciences

Students will have some familiarity with the idea of atoms and elements from science studies in grade three. In grade five the introduction to chemical reactions and the concept that atoms combine to form molecules require students to clearly distinguish between molecules and atoms and chemical compounds and mixtures. They will be introduced to the idea that the organization of atoms on the periodic table of the elements is related to similarities and trends in the chemical properties of the elements.

1. Elements and their combinations account for all the varied types of matter in the world. As a basis for understanding this concept:

a. *Students know* that during chemical reactions the atoms in the reactants rearrange to form products with different properties.

The properties of a chemical compound are controlled by the way atoms of different elements combine to make the compound. During a chemical reaction between two compounds, none of the original atoms are lost, but the atoms rearrange themselves into new combinations, resulting in the formation of products with properties that differ from those of the reacting compounds. Simple and safe chemistry experiments are described in fifth-grade science texts, and students can identify reactants and products when observing chemical reactions.

1. b. *Students know* all matter is made of atoms, which may combine to form molecules.

The fact that atoms can combine to form molecules is new information, and students should be given the opportunity to practice the correct use of those terms. The number of different types of atoms is relatively small in comparison with the large number of different types of molecules that may be formed. Simple molecules (such as nitrogen, oxygen, water, carbon dioxide, methane, and propane) can be easily represented by molecular models, and this depiction can enhance students' understanding of the symbolic representations in text. The idea of combinations of atoms sets the stage for learning about chemical bonds in high school.

1. c. *Students know* metals have properties in common, such as high electrical and thermal conductivity. Some metals, such as aluminum (Al), iron (Fe), nickel (Ni), copper (Cu), silver (Ag), and gold (Au), are pure elements; others, such as steel and brass, are composed of a combination of elemental metals.

Elements are grouped together on the periodic table of the elements according to their chemical properties, which in turn are based on the atomic structure of those elements. All pure, elemental metals share some properties in common, such as high electrical and thermal conductivity. Those same properties persist when elemental metals are combined to form alloys (e.g., copper and zinc to make brass).

Students may be familiar with many metallic elements (e.g., gold, silver, copper, zinc, aluminum, lead, mercury, chromium) and common metal alloys (e.g., brass, steel, bronze, pewter). It would be helpful for teachers to obtain samples of some of these metals and alloys for their students to study. (***Caution***: Some heavy metals [such as lead, mercury, and chromium, or their salts] may be hazardous.) In general, metals are shiny, reflecting most of the light that strikes them. They are malleable and ductile (that is, they will bend under pressure and are not brittle). They have a broad range of melting temperatures (e.g., mercury is a liquid at room temperature, gallium will melt in one's hand, and tungsten has a melting temperature

around 3,400 degrees Celsius). The thermal and electrical conductivity of all metals is high compared with nonmetallic substances, such as plastics and ceramics, rocks, and solid salts. Given the appropriate tools, students can develop tests for metals and nonmetals to determine whether they conduct electricity and heat.

1. d. *Students know* that each element is made of one kind of atom and that the elements are organized in the periodic table by their chemical properties.

All matter is made of atoms. The word *element* refers to those substances that repeated experiments have shown cannot be reduced to still more "elementary" substances. The explanation for this fact is that elements are made of many identical atoms. Water was considered an element at one time. However, it is possible to electrolyze water and produce hydrogen and oxygen gas, both elements. The properties of elements are determined entirely by their atoms. Therefore, elements are said to be made of one kind of atom that accounts for the element's unique properties. The history of the discovery and name of any one of the elements provides insight into the nature of science and scientific progress. The single most important property of an element is its atomic number. The number may be found on the periodic table along with the symbol and name of the element. Students should know that atomic numbers increase as they read from left to right and move line by line down the periodic table.

In grade eight students will be taught that the physical and chemical properties of an element are based on the internal structure of its atoms. The periodic table was originally constructed on the basis of increasing atomic weights of the elements. Those elements were organized in the pattern of a table, much like a monthly calendar, so that elements with similar chemical properties (e.g., metals, halogens, and noble gases) are grouped together in columns. The table gets its name because of the repeating, or periodic, sequences of chemical properties. Students should examine the periodic table of the elements and be able to locate elements by name. They should be able to find common metallic elements on the table and learn to refer to the table as they study and experiment with substances whose names are composites of the elements, such as sodium chloride and carbon dioxide.

1. e. *Students know* scientists have developed instruments that can create discrete images of atoms and molecules that show that the atoms and molecules often occur in well-ordered arrays.

The technique of electron microscopy has opened the door to a new generation of analytical tools that can be used to produce images of individual atoms in a crystalline array. Those images show atoms as "fuzzy balls" aligned in orderly and repeating patterns. From those images it is possible to infer that atoms are discrete objects of finite size and nearly spherical shape. Students may see images in textbooks and on the Internet that were obtained by using atomic-resolution instruments, such as electron microscopes and scanning tunneling microscopes. Those

images confirm, as hypothesized from years of indirect experimental evidence, that atoms in metals and crystals are arranged in orderly array. The images also show the presence of microfractures in which the order is interrupted, a condition that can affect the strength of the material.

1. f. *Students know* differences in chemical and physical properties of substances are used to separate mixtures and identify compounds.

Students should know the difference between mixtures and compounds. In compounds atomic constituents are separated by chemical rather than by physical means. In addition, every compound has a unique set of chemical and physical properties that can be used to identify it. Compounds and classes of compounds may be identified by chemical reactions with other compounds. An example is the iodine starch reaction. Other chemical reactions in solution may be explored to identify compounds based on changes in acidity, formation of precipitates, and changes in color. In mixtures the atomic constituents are separated by their physical properties. Simple and safe activities may be found in science texts for students in grade five. For example, iron filings can be separated from nonmetallic materials by use of a magnet, and a piece of filter paper can be used to separate suspended particles in a solution.

1. g. *Students know* properties of solid, liquid, and gaseous substances, such as sugar ($C_6H_{12}O_6$), water (H_2O), helium (He), oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2).

This standard builds on the previous one by challenging students to describe and identify a few common elements and compounds on the basis of observed chemical properties. Students can also study the three common physical states of matter for each of these compounds or elements as well as learn about and compare such properties as solubility in water, boiling and freezing points, sublimation, and reactivity.

1. h. *Students know* living organisms and most materials are composed of just a few elements.

By weight 98.59 percent of Earth's entire crust consists of eight elements: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. Nearly 3,500 known minerals are in Earth's crust. This fact shows that the complexity of the crust is also the result of a small number of elements in a large variety of combinations. Similarly, living organisms are mostly composed of the elements carbon, oxygen, hydrogen, nitrogen, sulfur, and phosphorus. The number of types of atoms used as "building blocks" is relatively small. The way in which the atoms are organized into molecules provides variety.

1. i. *Students know* the common properties of salts, such as sodium chloride (NaCl).

Elements and compounds may be described and identified on the basis of observed chemical and physical properties. Salts are compounds typically made from a metal and a nonmetal. Many salts are hard and brittle and have high melting temperatures. Most salts are soluble in water. When dissolved, they become conductors of electricity.

Salts are made when strong acids react with strong bases. For example, in the reaction of hydrochloric acid (HCl) with sodium hydroxide (NaOH), hydrogen (H) combines with hydroxide (OH) to form water while sodium (Na) and chlorine (Cl) ions remain in a solution that, if evaporated, would leave the salt sodium chloride (NaCl). Although the use of strong acids and bases in elementary classrooms would present a significant safety risk, science materials adopted for instruction in grade five describe simple experiments that can be safely conducted.

There are many different types of salts, but the general use of the term *salt* refers to sodium chloride, the most common and widely used. In science many salts are (but are not limited to) substances formed by elements in the groups under sodium and magnesium in combination with elements under fluorine. Some salts are poisonous, and students need to be cautioned not to ingest any substances used or produced in an experiment.

STANDARD SET 2. Life Sciences

In grade one students were presented with a simple example of the relationship between structure and function; namely, that the shapes of teeth are related to the types of materials animals eat. They subsequently learned to identify this phenomenon as an *adaptation.* Much of the discussion to this point has focused on external characteristics, but plants and animals have internal structures as well that perform vital functions. This subject, which is commonly called physiology, is developed still further in grade seven and in high school.

2. Plants and animals have structures for respiration, digestion, waste disposal, and transport of materials. As a basis for understanding this concept:

a. *Students know* many multicellular organisms have specialized structures to support the transport of materials.

Multicellular organisms usually have cells deep within them that need to receive a supply of food and oxygen and, in the case of animals, to have cellular wastes removed. In higher-order animals blood circulation is responsible for transporting glucose sugar to each cell, providing oxygen, and removing cellular wastes and

carbon dioxide. To demonstrate the transport of water in a plant, the teacher may cut the bottom end of a stalk of celery and place it in water containing food coloring. After the colored water is taken up into the plant, students can make cross-sections of the celery and observe them under a microscope. Observing the cross-sections is helpful to students in understanding Standard 2.e.

2. b. *Students know* how blood circulates through the heart chambers, lungs, and body and how carbon dioxide (CO_2) and oxygen (O_2) are exchanged in the lungs and tissues.

Structures of the cardiovascular and circulatory systems, including the heart and lungs, promote the circulation of blood and exchange of gas. The left side of the heart is responsible for pumping blood through arteries to all the tissues of the body and delivering oxygen. Oxygen-poor blood returns to the heart through veins; the right side of the heart is responsible for pumping this blood to the lungs, where the blood eliminates its carbon dioxide and receives a fresh supply of oxygen. Exhaling expels the carbon dioxide that was transported to the lungs by the blood; inhaling allows the intake of oxygen, which is picked up by the blood.

2. c. *Students know* the sequential steps of digestion and the roles of teeth and the mouth, esophagus, stomach, small intestine, large intestine, and colon in the function of the digestive system.

Digestion starts in the mouth, where chewing breaks down food into smaller pieces that can be easily swallowed and digested. Saliva contains compounds that are also important in breaking down food. The esophagus is a tube that moves food from the mouth to the stomach after swallowing. In the stomach the food is mixed with stomach acids that help to break down the food into parts that can be absorbed. Once food reaches the small intestine, it is neutralized and processed into molecules that can be absorbed into the blood supply. The large intestine recovers water from food, and the colon collects fecal waste (indigestible parts of food) and stores it prior to elimination from the body.

2. d. *Students know* the role of the kidney in removing cellular waste from blood and converting it into urine, which is stored in the bladder.

Cells in living organisms produce waste products that they cannot recycle into other compounds. The focus of this standard is on the systems that remove waste from the cells to prevent it from accumulating and eventually poisoning the organism. Cellular waste products (in the form of molecules) are separated from the bloodstream by the kidneys, stored in the bladder as urine, and removed from the body by urination. In plants many such waste products are stored in a large central vacuole in each plant cell—a kind of garbage dump that is gradually filled as the cell ages.

2. e. *Students know* how sugar, water, and minerals are transported in a vascular plant.

The *xylem* of plants is a woody tissue responsible for water and mineral transport from roots to leaves. Water moving up the plant stem replaces water that has evaporated from the leaves. Plants also transport sugar from the leaves to the roots through a living structure of tubes called the *phloem.*

2. f. *Students know* plants use carbon dioxide (CO_2) and energy from sunlight to build molecules of sugar and release oxygen.

Photosynthesis is the name of the process by which plants capture the energy of the sun and use it to initiate a chemical reaction between carbon dioxide and water that results in the production of sugar molecules and the release of oxygen molecules. The chemical process is as follows:

energy + carbon dioxide + water react to form sugar + oxygen

The process is expressed in the following equation:

$$\text{energy} + 6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

The sugar made during photosynthesis is just an initial compound the plant produces. All the other organic molecules are made by modification of this simple compound. For example, a significant portion of the mass of a log from a tree was once carbon dioxide gas in the air, captured by the leaves of a tree, and fixed into larger organic molecules as shown by the equation noted above. The sugar transport processes in the tree are also important in moving the products of photosynthesis down to the stem, where they could then become a part of the tree.

2. g. *Students know* plant and animal cells break down sugar to obtain energy, a process resulting in carbon dioxide (CO_2) and water (respiration).

Cellular respiration is a process of producing energy by the chemical breakdown of carbohydrate (sugar) molecules—a process that is the reverse of photosynthesis. The chemical process is as follows:

sugar + oxygen react to form carbon dioxide + water

The process is expressed in the following equation:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

Both plants and animals break down sugar to release its energy in a form they can use. This process is called *cellular respiration.* Carbon dioxide and water are reaction by-products. In animals the carbon dioxide is released into the blood, where it can be transported to the lungs. In the lungs carbon dioxide and oxygen are exchanged (which is the other use of the term *respiration*) during the act of breathing. It should be noted that cellular respiration is not the same as breathing.

STANDARD SET 3. Earth Sciences (Earth's Water)

The hydrologic cycle (water cycle) is the process by which water moves between the land and the oceans. Students in grade five learn that cooling in the atmosphere returns water vapor to a liquid or solid state as rain, hail, sleet, or snow. They are also introduced to factors that control clouds, precipitation, and other weather phenomena.

3. Water on Earth moves between the oceans and land through the processes of evaporation and condensation. As a basis for understanding this concept:

a. *Students know* most of Earth's water is present as salt water in the oceans, which cover most of Earth's surface.

Because water covers three-fourths of Earth's surface, this planet is sometimes referred to as the blue planet. Fresh water falls as rain on land and oceans alike. When it falls on land, the water dissolves salts and other mineral matter and carries them to the oceans. When water evaporates from the surface of the ocean, the salts remain behind and accumulate. For this reason the oceans have become salty. Students should know that the amount of fresh water on land is small compared with the amount in the oceans. Using science texts aligned with the *Science Content Standards* or a variety of library and other resources, students should be able to trace diagrams of the water cycle and understand what they represent.

3. b. *Students know* when liquid water evaporates, it turns into water vapor in the air and can reappear as a liquid when cooled or as a solid if cooled below the freezing point of water.

Liquid water evaporates and becomes invisible vapor when warmed by the sun. Water vapor mixes with the air as it moves through the atmosphere. When the air is cooled, a fraction of the water vapor changes back to liquid water in the form of clouds or rain. If the air temperature becomes low enough, the water will crystallize into a solid state as snow, sleet, or hail. Alternating periods of evaporation and precipitation drive the hydrologic cycle. For a laboratory demonstration a teacher may boil water to produce water vapor and direct the vapor onto the cold outside surface of a beaker filled with ice water. The precipitated water vapor will fog the outside of the beaker with tiny drops of liquid water.

3. c. *Students know* water vapor in the air moves from one place to another and can form fog or clouds, which are tiny droplets of water or ice, and can fall to Earth as rain, hail, sleet, or snow.

Atmospheric circulation moves water vapor, clouds, and fog from one place to another. The tiny droplets or crystals of water that form fog and clouds are so small

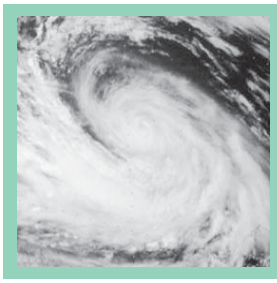
that they remain suspended in the air. Further cooling of the air can cause these droplets or crystals to grow sufficiently until they fall to the earth as rain, hail, sleet, or snow. By learning basic meteorology from texts and monitoring and plotting local weather data reported by the news media, students can explore the relationship between the amount of water vapor in the air (humidity), air temperature, and the likelihood of rainfall or snowfall.

3. d. *Students know* that the amount of fresh water located in rivers, lakes, underground sources, and glaciers is limited and that its availability can be extended by recycling and decreasing the use of water.

Students learn that water quality is affected by various uses and that there are local, state, federal, and global efforts to manage water resources. In California, water resources depend on the use of annual rainwater (and snowpack water) collected in watershed districts, pumping of groundwater, import of water from rivers, and reclamation of water that has been used. Water quality in streams is affected by the disturbance or development of land in a watershed area, runoff of water from farms and city streets, and projects that control the flow of rivers in a flood basin.

3. e. *Students know* the origin of the water used by their local communities.

Students learn the origins of the local water supply through a study of the watershed, creeks, rivers, aqueducts, dams, and reservoirs that serve as its source. Students should know whether their community's balance between water supply and demand varies seasonally and whether conservation and reclamation techniques are practiced. If water is imported, students should be able to trace it back to its source or sources.



STANDARD SET 4. Earth Sciences (Weather)

Students in grade five learn about the causes of large-scale and small-scale movements in the atmosphere. They apply knowledge of the hydrologic cycle to understanding weather and weather patterns.

4. Energy from the Sun heats Earth unevenly, causing air movements that result in changing weather patterns. As a basis for understanding this concept:

a. *Students know* uneven heating of Earth causes air movements (convection currents).

The atmosphere and surface of Earth are heated unevenly, giving rise to both local and global temperature differences. For example, the direct heat absorbed by

the surface of the ocean, land, and air may result in different temperatures. Furthermore, the amount of heat varies with latitude, primarily because of the height of the Sun in the sky. The lower the Sun's elevation, the less direct is its radiation and the less radiation that falls on each square meter of Earth's surface area. This event is a result of geometry and depends on the angle at which the Sun's rays intersect Earth's surface at a locality. When the incoming rays of the Sun intersect Earth's surface at a more oblique angle, the solar flux is spread out over a wider area. Polar regions are cold because the Sun is low in the sky and its rays fall at very large angles. Closer to the equator, the Sun's rays fall more directly and the climate is hot. The uneven heating results in local and global temperature differences that create convection currents in the oceans and atmosphere. Students in grade five should know that warm air rises and cold air falls toward Earth's surface, setting up convection currents in the air that are called *winds.*

Convection is an important mechanism in moving heat around in Earth's mantle, in the oceans, and in the atmosphere. The process of hot air rising and cold air sinking occurs at Earth's surface on many different scales, causing local winds and great global air currents, such as the trade winds.

4. b. *Students know* the influence that the ocean has on the weather and the role that the water cycle plays in weather patterns.

Because Earth is a sphere, equatorial regions receive more concentrated sunlight than do polar regions. Temperatures are therefore higher at the equator than farther north or south, but the difference would be much more extreme without the influence of the oceans, which cover about 70 percent of Earth's surface. Large bodies of water can absorb (or release) a great deal of heat without changing temperature very much; their temperature stays relatively constant from day to night and from season to season. Oceanic circulation carries water warmed near the equator to the north and to the south. The great ocean currents help distribute heat from place to place by gradually releasing it into Earth's atmosphere. Warm surface currents (such as the Gulf Stream) make high-latitude countries (such as Scotland) more habitable than they would otherwise be. Moreover, a great amount of equatorial heat is absorbed by water during evaporation. Global atmospheric currents (winds) carry the water vapor to cooler regions, and heat is released to the atmosphere as the vapor condenses, forming precipitation. Thus heat as well as water is transported, providing an important mechanism for evening out temperatures on Earth.

Air in contact with large bodies of water is *tempered*—warmed in the winter and cooled in the summer. The amount and distribution of precipitation depend a great deal on the surface temperature of the water. When water temperatures do change, even a little, large changes in weather patterns may occur. A good example of this is the ENSO (El Niño/Southern Oscillation) cycle, which brings especially wet and dry seasons to many places around the world.

4. c. *Students know* the causes and effects of different types of severe weather.

Many types of severe weather are in the world: hurricanes, tornadoes, thunderstorms, and monsoons. The source of energy for all weather is the Sun, which heats air and water unevenly. Warm air tends to be less dense than cold air, and air will always flow (blow) from areas of high pressure (denser air) toward areas of lower pressure, creating winds. With increasing temperature, more water can evaporate into the air. When this warm, moist air is suddenly cooled (as by contact with a cold air mass), condensation and precipitation may result. The contacts between air masses with different temperatures are called *fronts.* When a patch of warm, low-pressure air is surrounded by higher-pressure air (called a low-pressure "closure"), the warmer air will tend to rise and be replaced, through convection, by high-pressure air flowing in from all around. Because Earth rotates on its axis, all such winds are deflected (turned to the right in the Northern Hemisphere and to the left in the Southern); the net effect is a circular wind, which surrounds the low-pressure closure. The rising warm air in the center cools, its water condenses, and precipitation occurs. This phenomenon is known as a *cyclone* and is the cause of many big hurricanes and other storms.

4. d. *Students know* how to use weather maps and data to predict local weather and know that weather forecasts depend on many variables.

Weather maps display data on air temperature, air pressure, and precipitation. If students know that air flows from regions of high pressure to regions of low pressure (and turns to the right in the Northern Hemisphere), they can look at a weather map and predict the direction of the wind. If they know, for example, that weather fronts tend to move from west to east in North America, they can predict tomorrow's weather in one place by checking on today's weather somewhere else. And if they see low-pressure closures (discussed above), they can predict stormy or fair weather from high-pressure closures. Very small changes in temperature and pressure, however, may significantly change all such patterns over a few days (the so-called chaos theory). Long-term weather forecasts tend to be unreliable for this reason.

4. e. *Students know* that the Earth's atmosphere exerts a pressure that decreases with distance above Earth's surface and that at any point it exerts this pressure equally in all directions.

Atmospheric pressure is the weight of air (a force) pushing on a given square unit area (e.g., m^2 or cm^2). Air is invisible, hard to detect by the sense of touch, and difficult to weigh. Thinking of air as being able to exert pressure works against one's intuition; nonetheless, air has mass and anything with mass is pulled by gravity toward Earth's center. This principle means that atmospheric pressure is greatest near Earth's surface at sea level and diminishes with increasing height in the atmosphere.

This effect is used by airplane pilots to measure altitude reliably, with barometric pressure at sea level serving as a reference point. The principle also means the pressure exerted on the bottom of an object, such as a balloon, is slightly greater than the pressure on the top. The second part of this standard is a reminder that the direction of the "push" caused by the pressure is the same in all directions—up, down, or sideways. The same principle holds true for pressure in any fluid.

STANDARD SET 5. Earth Sciences (The Solar System)

Student knowledge of the solar system includes an understanding of and the ability to describe the relative motions of the planets. Students already know that Earth orbits the Sun and the Moon orbits Earth. Students in grade five learn the composition of the Sun and that the solar system includes small bodies, such as asteroids and comets, as well as the Sun, nine planets, and their moons. They learn the basic relationship between gravity and the planetary orbits.

5. The solar system consists of planets and other bodies that orbit the Sun in predictable paths. As a basis for understanding this concept:

a. *Students know* the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.

The Sun is about one million times the volume of Earth. Its mass can be calculated from the shapes of the planetary orbits, which result from the gravitational attraction between the Sun and its planets. The fusion of hydrogen to helium produces most of the Sun's energy.

5. b. *Students know* the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.

The solar system comprises nine planets, in the following order from the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. Most of the planets have moons in orbit about them, but only Earth's moon is visible to the unaided eye. Asteroids and comets are small bodies, most of which are in irregular orbits about the Sun. Many science texts and Web sites provide information and photographs of objects in the solar system that are collected from NASA's planetary, comet, and asteroid missions and from the use of Earth and space telescopes.

5. c. *Students know* the path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.

Planets move in elliptical but nearly circular orbits around the Sun just as the Moon moves in a nearly circular orbit around Earth. Each object in the solar system

would move in a straight line if it were not pulled or pushed by a force. Gravity causes a pull, or attraction, between the mass (matter) of each of the planets and the mass (matter) of the Sun. This pull is what continually deflects a planet's path toward the Sun and produces its orbit.

Students may wonder why the pull of gravity does not cause the planets to "fall" into the Sun or the Moon into Earth. One explanation is that the planets and Moon are in fact falling, but they are also moving very fast to the side. As the Moon is pulled toward Earth, it also moves forward creating the curved path of its orbit. Thus the Moon is constantly falling, but the downward and sideways motions are exactly balanced so that the Moon never gets closer to or farther away from Earth. In the same way the planets are maintained in orbits around the Sun. Understanding that gravity exists in outer space may be made more difficult by the images of astronauts floating "weightless" in their capsules. When these pictures are taken, the astronauts are in orbit around Earth and are essentially free-falling (just like the Moon).

STANDARD SET 6. Investigation and Experimentation

Questions that are testable in science are founded on factual information and are based on observations. When students plan an experiment on the basis of their questions, they must decide what the variables are or what properties or sequence of events will change throughout the experiment. Students will observe and measure a change in one of the properties or event sequences in their experiment. The experiment is complete when the students draw conclusions and make inferences in a written or oral report or in both.

6. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- **a.** Classify objects (e.g., rocks, plants, leaves) in accordance with appropriate criteria.
- **b.** Develop a testable question.
- **c.** Plan and conduct a simple investigation based on a student-developed question and write instructions others can follow to carry out the procedure.
- **d.** Identify the dependent and controlled variables in an investigation.
- **e.** Identify a single independent variable in a scientific investigation and explain how this variable can be used to collect information to answer a question about the results of the experiment.

f. Select appropriate tools (e.g., thermometers, metersticks, balances, and graduated cylinders) and make quantitative observations.

g. Record data by using appropriate graphic representations (including charts, graphs, and labeled diagrams) and make inferences based on those data.

h. Draw conclusions from scientific evidence and indicate whether further information is needed to support a specific conclusion.

i. Write a report of an investigation that includes conducting tests, collecting data or examining evidence, and drawing conclusions.

Notes

1. *Science Safety Handbook for California Public Schools.* Sacramento: California Department of Education, 1999.
2. *Mathematics Content Standards for California Public Schools, Kindergarten Through Grade Twelve.* Sacramento: California Department of Education, 1999.
3. *Science Content Standards for California Public Schools, Kindergarten Through Grade Twelve.* Sacramento: California Department of Education, 2000; *English–Language Arts Content Standards for California Public Schools, Kindergarten Through Grade Twelve.* Sacramento: California Department of Education, 1998.